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Navy Radiological Systems Performance Evaluation Manual

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BUREAU OF MEDICINE AND SURGERY

Navy Radiological Systems Performance Evaluation Manual

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Navy Radiological Systems Performance Evaluation Manual

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Chapter 1

Navy Radiological Systems Performance Evaluation Manual

Introduction

Background:

This manual has been prepared to provide the surveyor with standard procedures for acceptance and periodic testing of diagnostic radiological systems throughout the Navy. It provides a uniform methodology for testing equipment and reporting results. Standardized procedures ensure that appropriate parameters are evaluated, provide a means of comparison of results between facilities, among surveyors, between manufacturers and individual systems from a single manufacturer**,** and allow objective program evaluation. This will allow trending of problem equipment, identification of training deficiencies and will provide a means of tracking corrective actions.

This manual establishes for diagnostic radiological systems periodicity of surveys, parameters to be measured, training and qualification of surveyors, and reporting requirements. The manual does not address therapeutic radiological systems. Navy radiation oncology departments shall establish departmental quality assurance programs in accordance with accepted national protocols, including qualification standards for personnel performing equipment quality control and acceptance testing.

The manual provides guidance for performing survey measurements which will be instructional for surveyors-in-training. It may also be of use to diagnostic radiologists and biomedical equipment repair technicians.

Extent of Surveys:

In addition to the survey periodicity listed in the following chapters, diagnostic radiological systems should be surveyed prior to first clinical use (acceptance) and after major repairs. Invasive acceptance testing is complex and time-consuming since almost all combinations of variable settings are evaluated. Detailed acceptance testing procedures are covered in this manual for diagnostic x-ray equipment acceptance testing procedures. The Defense Supply Center Philadelphia (DSCP) [formerly Defense Personnel Support Center (DPSC)] can provide current specifications for newly procured systems. Non-invasive periodic testing is less rigorous and should cover only the range of clinical use. Testing after repairs is limited to those parameters potentially affected by the work performed.

The optimal radiation protection survey should include communication between clinicians, radiological technologists, repair technicians and surveyors. Equipment parameters, operational procedures, patient exposures and related factors should be evaluated. Prior to the survey, coordination with facility personnel is necessary to ensure equipment is operational and available for testing. Prior to leaving the facility, significant findings should be discussed with facility personnel responsible for ensuring equipment repairs are completed.

Radiation Protection:

X-ray producing machines are tested for technical performance and radiation safety. The objective of an effective x-ray survey program is to provide a safe diagnostic tool that benefits both the patient and the medical practitioner while at the same time keeps radiation exposure as low as reasonably achievable (ALARA), i.e., to obtain optimal image quality while minimizing patient and operator exposure.

Radiation dose received by patients may be decreased by elimination of procedures that are unnecessary or are of marginal value. Additionally, use of high speed image receptors and ensuring that x-ray equipment is operating in compliance with the Radiation Control for Health and Safety Act of 1968, etc. are other methods to reduce patient dose.

Radiation dose received by medical, dental and allied health personnel must also be minimized.

Fundamental methods include the provision of protective barriers, protective clothing and the implementation of appropriate operational procedures. A well-managed dosimetry program for all medical x-ray personnel is also very important. When performing radiological equipment surveys at outside commands, qualified Radiation Health Officers should make themselves available to perform the command's annual external Radiation Health Program audit as required by NAVMED P-5055, Navy Radiation Health Protection Manual, paragraph 1-6(1)(b).

Training and Qualification:

Training guidelines for qualification as a surveyor at each of the three levels are established by the Medical Physics Advisory Board (MPAB). The MPAB will consider both formal didactic training and individual mentored experience in establishing training guidelines. Individuals applying to be designated as a qualified surveyor will complete and submit an application package obtained from the Navy Environmental Health Center (NEHC). The Radiation Health Officer/Radiation Specialist Specialty Leader (BUMED, MED-211) will approve all qualified surveyors. Personnel Qualification Standards (PQS) will be maintained by NEHC to document the training of individual surveyors.

Examples of formal didactic training include survey courses offered at the U.S. Army Medical Department Center and School (AMEDDC&S) at Ft Sam Houston, Texas, 78234-6100, and the Radiological Systems Performance Evaluation Course (Service School Code 021) at the Uniformed Services University of the Health Sciences (USUHS).

The senior qualified physicist at each Naval Medical Center and at USUHS may mentor surveyors and submit qualifications and preceptor statements for final approval to BUMED via NEHC. Other Navy physicists qualified as surveyors at the appropriate level can provide mentored training with prior approval from the Specialty Leader. The preceptors shall ensure the trainee is competent to independently survey each system at the appropriate qualification level prior to endorsing the trainee's qualification package. Surveys by trainees shall be mentored and countersigned by the preceptor.

Physicists certified by the American Board of Radiology (ABR) are considered qualified to survey any diagnostic or therapeutic unit in the field in which they are certified. Special qualifications are needed by the physicist of record for mammography surveys, in accordance with the Mammography Quality Standards Act (MQSA) of 1992.

All qualified surveyors are required to obtain continuing education hours as well as maintain continuing experience. Annual peer review of all surveyors will be performed by the MPAB.

Qualification Levels:

There are three levels of surveyor qualification: Basic X-ray (Level I), Intermediate Radiological Systems (Level II), and Advanced Radiological Systems (Level III). Surveyors shall be fully qualified at Level I before progressing to Level II. Surveyors shall be fully qualified for all systems included in qualification levels I and II before being approved as a surveyor at those levels. Surveyors may be qualified for sublevels (individual systems) within Level III.

The basic x-ray surveyor shall be qualified to perform surveys of A) general radiographic units, B) dental radiographic units, C) general fluoroscopic units and D) evaluation of film processor and darkroom quality control programs.

The intermediate radiological systems surveyor shall be qualified to perform surveys of: A) fluoroscopic c-arm units, B) urologic units, C) tomographic units, D) computed tomographic (CT) units, E) ultrasound scanners, F) nuclear medicine imaging systems and G) establishment of quality control programs.

The advanced radiological systems surveyor shall be qualified to perform surveys and acceptance testing of: A) CT units, B) advanced x-ray systems including interventional, angiographic, DSA and cardiac catheterization, C) magnetic resonance imaging (MRI) systems, D) ultrasound scanners, E) nuclear medicine imaging systems, and F) mammographic units.

A qualified officer surveyor must countersign all surveys performed by surveyors-in-training and technicians. In order to countersign a survey, the qualified surveyor must have personally trained and qualified the individual performing the survey in the survey procedures for the equipment being evaluated.

Qualification levels are summarized in Appendix A.

Reports:

Reports document the parameters evaluated during the survey. A cover letter adequately describing any equipment discrepancies and recommended corrective actions, as well as any entrance skin exposures measured and repeat rate analysis reviewed must be sent to the facility possessing the unit surveyed. The facility shall forward corrective action reports to the surveyor within 30 days. The surveyor shall be responsible for tracking correction actions and shall report all corrective action reports delinquent over 60 days to NEHC for further action.

Each discrepancy shall be identified as minor or significant at the discretion of the surveyor. Significant discrepancies are those which impact patient/operator safety or image quality. Summary reports of each x-ray survey are to be provided to the Navy Environmental Health Center (NEHC). The entire survey package is not to be forwarded. Surveyors will use the current NEHC approved computerized reporting system to submit summary information on all surveys, except mammographic systems, which must have a hard copy of the survey submitted. The current software version can be obtained from the NEHC Radiation Health Team.

How to Use This Manual:

Each of the following chapters in this manual lists the required tests for each type of x-ray unit or procedure, and the frequency and tolerances to which they should be performed. Additionally, the level of training appropriate for the particular unit being surveyed is provided. Supplementary recommended references are also included. Appendices contain detailed survey testing procedures. Surveyors may use these or other acceptable protocols. Additional tests not listed may be performed, as needed.

Some sample forms are included which are recommended to document x-ray surveys. Locally produced forms may be used if they contain all required information.

Chapter 2

General Radiographic Units
Fixed and Portable

Minimum Required Personnel Qualifications:

Level 1 (Basic X-Ray Surveyor)

Testing Periodicity:

1. Ashore Facilities:	Annually
2. Afloat Units:	Every 24 months
3. Deployed medical units:	Prior to fielding
4. Hospital ships:	Annually
5. Veterinary clinics:	Every 24 months
7. All units:	Upon acceptance

Instrumentation:

1. Electrometer with small ion chamber
2. Level
3. kVp meter
4. Light meter
5. Type 1100 10 x 10 cm Aluminum plates (9 mm total, three 2 mm, two 1.0 mm, two 0.5 mm thicknesses)
6. Timer tester (may be part of exposure meter)
7. Focal spot test tools (one of the following)
   a. slit camera
   b. right cylinder power target
   c. Siemens Star (1.0 degree)
8. Acrylic 2 cm thickness 10 x 10 cm plates (3 each)
9. Collimator test tool (one of the following)
   a. copper plate (marked from center to edge in either centimeters or inches)
   b. Five coins
10. X-ray beam alignment test tool (if available)
11. AEC Backup Timer Test Tool: Lead plate (at least 3.2 mm x 20 x 20 cm)
12. Tape measure
13. Cardboard cassette or ready pack film
14. Copper plate, 1.6 mm x 10 x 10 cm
15. Optional
   a. BRH test stand
   b. AEC test cassette

References

1. AAPM Report 31, *Standardized Methods for Measuring Diagnostic X-ray Exposures*. 1990.
2. Code of Federal Regulations, Title 21, Chapter 1, Section 1020.30, 1020.31, 1020.32; 3 May 1993 edition.
3. Curry, T.S. III, Dowdey J.E., Murry, R.C. Jr. *Christensen's Physics of Diagnostic Radiology*. Lea & Febiger, Philadelphia. 1990.
4. Gray, J.E., Winkler, N.T., Stears, J., Frank, E.D. *Quality Control in Diagnostic Imaging*; University Park Press, Baltimore, 1983.
5. Hendee, W.R., Chaney, E.L., Rossi, R.P. *Radiologic Physics, Equipment and Quality Control*, Year Book Medical Publishers, Inc., Chicago, 1977.
6. NCRP Report 99, *Quality Assurance for Diagnostic Imaging Equipment*, National Council on Radiation Protection and Measurements, Bethesda, 1988.

Table 2.1: General Radiographic Unit Survey Requirements

	Test	Frequency	Measurements	Tolerance
1.	**Exposure Reproducibility**	A	10 repeat measurements	cv<0.05
		P	4 repeat measurements	if cv>0.05, do 4 more
2.	**Timer Reproducibility**	A P	10 repeat measurements 4 repeat measurements (all at 100mSec)	cv<0.05 cv<0.05 if>0.05, 4 more
3.	**Timer accuracy**	A	From 1 second to the minimum timer setting in increments of decreasing time of 50%.	±10% of nominal setting
		P	minimum and 1 second plus 3 others evenly spaced between	±10% of nominal setting
4.	**Linearity of mA/mAS**	A P	all focal spots, all mA stations. If continuous, in 100 mA increments from min to max 5 adjacent mA stations over range of clinical use	Change <0.1 of the sum of measurements at adjacent mA stations Will see differences if incoming power is inadequate
5.	**kVp Accuracy**	A	for each generator: from 50 up to the maximum kVp setting by 5's	±5% of nominal setting
		P	for each generator: from 60 up to the maximum kVp setting by 20's	±5% of nominal setting
6.	**Beam Quality**	A/P	@ 80 kVp, 1st HVL	Minimum HVL of 2.3 mm Al
7.	**Output Linearity tracking by KVP**	A P	Max mAs at each kV by 10's - from 50-150 60, 80, 100 kVp at constant mAs	R ≥ 0.990 (Linear Correlation Coefficient)
8.	**Light Field Intensity**	A/P	Average of 4 quadrants of 25x30 cm light field	Average illuminance ≥ 160 lux (15 ftcd) at 100 cm or at the max SID whichever is less
9.	**Light field/x-ray beam alignment**	A/P	Set any clinically used field size (e.g. 18 x 24 cm)	Total misalignment of edges of light field vs x-ray field not to exceed 2% of SID along either length or width
9a.	**X-ray field size - indicated vs actual**	A/P	Set any clinically used field size (e.g. 18 x 24 cm)	± 2% SID

Abbreviations: A: acceptance, P: periodic, cv: Coefficient of variation, KVP: kilovolt peak, F.S.: focal spot, mA: milliamp, HVL: half value layer, MAS: millamp seconds, ftcd: foot candle, cm: centimeters, SID: source-to-image distance, PBL: positive beam limitation, AEC: automatic exposure control, OD: optical density, OD_{BL}: optical density baseline, DCF: density control function, ESE: entrance skin exposure, AP: anterior to posterior, L: lumbar, C: cervical, PA: posterior to anterior, LP: line pairs

Table 2.1: General Radiographic Unit Survey Requirements, continued

	Test	Frequency	Measurements	Tolerance
10.	**Central Beam Alignment**	A/P	Measurement of perpendicularity of central beam.	5 mm
11.	**Indicated SID**	A/P	Measuring tape vs indicated distance	± 2% SID
12.	**PBL**	A/P	With x-ray, 1 cassette size bi-directional all other sizes use light field	± 3% SID centers ± 3% SID
13a.	**Focal Spot Size** (for focal spots < 1.0 mm)	A/P	Use star pattern (Slit camera or pinhole camera may be used)	anode-cathode direction: perp: 1.5x nom parallel: 2.15 x nom
13b.	**Focal spot constancy** (alternative method for period evaluation**)**	A/P	RMI power target perp and parallel to anode-cathode axis @ 80KVP, 100mA, 8mS	Perp _LP Parallel_LP
14.	**AEC** **a. OD**	A/P	Table and Wall DCF = 0, 4 cm Al phantom	 $OD = OD_{BL} \pm 0.15$ at center of field (OD_{BL} must be > 1.2)
	b. thickness compensation		Check each detector at 2 and 4 cm Al thicknesses	$OD = OD_{BL} \pm 0.3$
	c. kVp compensation		70, 90, 110 kVp	$OD = OD_{BL} \pm 0.3$
	d. DCF tracking		All DCF settings	should vary as expected, approx 25% between settings
	e. reproducibility		3 exposures each detector	All ≤ ± 5% of mean
	f. balance		Center to each side	$OD = OD_{BL} \pm 0.1$
	g. Back-up timer		Max exp time, Pb over all detectors	Elapsed < 600 mAs or 2000 mAs for tube potentials < 50 kV
15.	**ESE Measurement**	A/P	PA Chest (wall bucky), AP Abdomen, C spine, Lat Skull, extremity	± 20% most recent NEXT report

Abbreviations: A: acceptance, P: periodic, cv: Coefficient of variation, KVP: kilovolt peak, F.S.: focal spot, mA: milliamp, HVL: half value layer, MAS: millamp seconds, ftcd: foot candle, cm: centimeters, SID: source-to-image distance, PBL: positive beam limitation, AEC: automatic exposure control, OD: optical density, OD_{BL}: optical density baseline, DCF: density control function, ESE: entrance skin exposure, AP: anterior to posterior, L: lumbar, C: cervical, PA: posterior to anterior, LP: line pairs

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Chapter 3

Dental Radiographic Units
Intraoral and Panographic

Introduction (Intraoral)

1. This unit is one of the simplest x-ray machines to evaluate.
2. The low output is the biggest obstacle to performing a survey, but this can be overcome by increasing exposure time or decreasing the target to chamber distance.
3. Record the settings of all variable controls on the control console and return to these settings at the end of the survey.

Introduction (Panoramic)

1. The panoramic dental x-ray unit is a challenge for even the most experienced physicist. The arcing motion of the tube head during exposure along with the thinly collimated beam make measurement of output parameters difficult at best.

2. The following parameters may, however, be evaluated, without too much difficulty:

   a. Timer accuracy;
   b. Beam quality; and,
   c. Beam/film slit alignment

Minimum Required Personnel Qualifications:

Level 1 (Basic X-ray Surveyor)

Testing Periodicity:

All units: Every 24 months, upon acceptance and after major repairs

Instrumentation:

1. Electrometer with small ion chamber
2. kVp meter
3. Pulse counter
4. Type 1100 10 x 10 cm Aluminum plates (varying thicknesses; at least 5mm total)
5. Stopwatch
6. Tape measure
7. Cardboard cassette or ready pack film
8. Surgical adhesive tape
9. Fluorescent screen or bitewing film
10. Optional: BRH test stand

References

1. AAPM Report 31, *Standardized Methods for Measuring Diagnostic X-ray Exposures*. 1990.
2. Code of Federal Regulations, Title 21, Chapter 1, Section 1020.30, 1020.31, 1020.32; 3 May 1993 edition.
3. Curry, T.S. III, Dowdey J.E., Murry, R.C. Jr. *Christensen's Physics of Diagnostic Radiology*. Lea & Febiger, Philadelphia. 1990.
4. Gray, J.E., Winkler, N.T., Stears, J., Frank, E.D. *Quality Control in Diagnostic Imaging*; University Park Press, Baltimore, 1983.

Table 3.1: Dental Intraoral Unit Survey Requirements

	Test	Frequency	Measurements	Tolerance
1	**Exposure Reproducibility, Timer Reproducibility, Timer Accuracy, Linearity of mR/mAS, kVp Accuracy, kVp precision**	Same as steps 1 - 6 for General Radiographic Unit Survey Requirements. See Table 2.1, Chapter 2.		
2	**X-ray Beam Quality**	A/P	@ 70 kVp, 1st HVL	HVL of 1.5 mm Al or greater
3.	**X-ray field size/cone alignment**	A/P	Measure x-ray beam alignment with end of cone	x-ray field size of 2.5 cm Beam aligns with cone
4.	**Minimum SSD**	A/P	SSD $\geq$ 18 cm SSD < 18 cm	Diameter of x-ray field $\leq$ 7 cm Diameter of x-ray field $\leq$ 6 cm

Abbreviations: A: acceptance, P: periodic, HVL: half value layer, kVp: kilovolt peak, mA: milliamp, mAS: milliamp seconds, SSD: source to skin distance

Table 3.2: Dental Panoramic Unit Survey Requirements

	Test	Frequency	Measurements	Tolerance
1	**Exposure Reproducibility**	Same as step 1 for General Radiographic Unit Survey Requirements. See Table 2.1, Chapter 2.		
2	**Duration of Exposure Cycle**	A/P	Measure during exposure reproducibility	± 1 Second
3	**mAS Linearity**	A/P	Measure at 2 mA stations if available	
4.	**X-ray Beam Quality**	A/P	@ 70 kVp, 1st HVL	HVL of 1.5 mm Al or greater
5	**X-ray Beam/Slit Alignment**	A/P	View beam slit fluoresence using fluorescent sreen or: Expose 2 pieces of intraoral film taped diagonally across beam slit or use ready pack	View of entire film slit Diagonal line across each film from corner to corner Mark slit on film

Abbreviations: A: acceptance, P: periodic, HVL: half value layer, kVp: kilovolt peak, mA: milliamp, mAS: milliamp seconds

Chapter 4

General Fluoroscopic Units

Minimum Required Personnel Qualifications:

Level I (Basic X-ray Surveyor)

Testing Periodicity:

All units: Annually, upon acceptance and after major repairs

Instrumentation:

1. Electrometer with large and small ion chambers ($6\ cm^3$ and $180\ cm^3$ nominal vols)
2. 10+ step Aluminum wedge (digital RF units)
3. Exposure rate compatible digital kVp meter
4. High resolution test patterns
   a. RMI® 141, 141-H (low/high level)
5. Penetrameter kit
   a. 2 Al plates (17.8 cm x 17.8 cm x 1.9 cm)
   b. Lead plate (20 cm x 20 cm x 1.6 mm)
   c. 1.5, 3.1, 4.7, & 6.3 mm perf. Al sheet (17.8 cm x 17.8 cm x 0.8 mm)
6. 1100 Al alloy sheets (10 cm x 10 cm) (varying thicknesses; at least 5 mm total)
7. Densitometer
8. Collimator/beam alignment test tool
   a. Etched plate (25 cm x 20 cm x 1.5 mm)
   b. Plastic cylinder with imbedded steel balls
   c. Two dimensional level
9. Tape measure
10. Film/screen cassette with appropriate film (14” x 17”, 35 cm x 43 cm)
11. Optional
    a. BRH test stand
    b. Screen-film contact test tool
    c. Copper plate (20 cm x 20 cm x 1.5 mm)
    d. Acrylic phantom (30 cm x 30 cm x 18+ cm)

References:

1. AAPM Report 12. *Evaluation of Radiation Exposure Levels in Cine Cardiac Catheterization Laboratories*, 1984.
2. AAPM Report 25. *Protocols for the Radiation Safety Surveys of Diagnostic Radiological Equipment*, 1988.
3. AAPM Report 35. *Recommendations on Performance Characteristics of Diagnostic Exposure Meters*, 1992.
4. Chakraborty, D.P. *Routine Fluoroscopic Quality Control*, 1991 AAPM Summer School Proceedings, 1994.
5. Code of Federal Regulations, Title 21, Chapter 1, Section 1020.30, 1020.31, 1020.32; 1 April 1996 edition.
6. Curry, T.S. III, Dowdey J.E., Murry, R.C. Jr. *Christensen's Physics of Diagnostic Radiology, Fourth Edition*, Lea & Febiger, Philadelphia. 1990.
7. Gray, J.E., Winkler, N.T., Stears, J., Frank, E.D. *Quality Control in Diagnostic Imaging*, University Park Press, Baltimore, 1983.
8. Lin, P.J.P. *Technical Considerations of Equipment Selection and Acceptance Testing of Cardiovascular Angiography Systems,* 1991 AAPM Summer School Proceedings, 1994.
9. NCRP Report 99. *Quality Assurance for Diagnostic Imaging Equipment*, 1988.
10. *Quality Assurance for Fluoroscopic X-ray Units and Associated Equipment*, Bureau of Radiological Health, Rockville, MD; October 1979.

Table 4.1: General Fluoroscopic Unit Survey Requirements

	Test	Freq	Measurements	Tolerance
1.	**kVp Accuracy**	A	50 kVp to max in 5 kVp increments	± 5 % of nominal setting or readout
		P	50 kVp to max in 10 kVp increments If manual kV control isn't available, use ABC provided voltage	Same as acceptance
2.	**Entrance Exposure Rate (EER)**	A/P	All available output modes [manual, ABC (NL & HLC), pulse, cine] at each available II size, 4 cm Al*	A. Less than max EER P. No sig change from acceptance (± 10 %)
3.	**Maximum Entrance Exposure Rate (Max EER)**	A/P	All available output modes [manual (at max kVp), ABC (NL & HLC), pulse, cine] at largest II size. 4 cm Al phantom + Pb sheet	See table C-1
4.	**Transmission Through Primary Barrier**	A/P	Al phantom + Pb sheet set as for Test 3., max EER technique Large volume ion chamber	1 mRh^{-1} @ 10 cm from primary barrier rear surface per ESE $Rmin^{-1}$
5.	**Beam Quality (HVL)**	A/P	Manual mode - 90 kVp	2.5 mm ≤ x ≤ 3.5 mm 1100 Al alloy
			ABC only - kVp provided by unit for 5 mm Al in beam	x ≥ min allowed for kVp; see Table A-1
6.	**Minimum SSD**	A/P	Directly using tape measure or indirectly through triangulation	≥ 38 cm (stationary) ≥ 30 cm (conv C-arm) ≥ 20 cm (surg C-arm) Never < 20 cm
7a.	**Beam Limitation (Minimum Field Size)**	A/P	Max SID, minimum collimation, film at II face	Dark area ≤ 5 x 5 cm^2
7b.	**Maximum Field Size**	A/P	Max SID, widest collimation, max II size, film at II face	Dark area ≤ maximum nominal II size Collimator tracks with changing SID
8.	**Fluoro Display Field Alignment**	A	Largest II size, collimator blades visible in TV image, film at II face, etched plate at table top For variable SID units: determine at minimum and maximum SID	Diff between film and screen X or Y axis lengths ≤ 3 % of SID Sum of X & Y axis diff ≤ 4 % of SID
		P	Test at largest II size, min SID only	Same as acceptance
9.	**Beam Central Alignment**	A/P	Minimum SID, max II size, widest collimation	≤ 1.5 degrees from vertical

* Alternatively use 15 cm thick acrylic phantom, if available.

Abbreviations: A: acceptance, P: periodic, kV: kilovolt, kVp: kilovolt peak, HVL: half value layer, cm: centimeters, SID: source-to-image distance, OD: optical density, OD_{BL}: optical density baseline, ESE: entrance skin exposure, ABC: automatic brightness control, HLC: High level control, NL: Normal, Al: aluminum, Pb: lead, FOV: field of view, SSD: source-to-skin distance, AEC: automatic exposure control, II: image intensifier, medium setting: mean available technique setting for the given output mode.

Table 4.1: General Fluoroscopic Unit Survey Requirements, Continued

	Test	Freq	Measurements	Tolerance
10a.	**Pin-Cushion Distortion**	A/P	Manual or ABC (NL) mode at largest II size	Spatial linearity visually uniform over center 75 % of FOV
10b.	**"S-ing" Distortion**	A/P	Manual or ABC (NL) mode at largest II size	Etched plate lines visually linear along X & Y axes in center 75 % of FOV
11.	**High Contrast Resolution**	A	All available output modes [manual, ABC (NL & HLC), pulse, cine, spot (digital & mech.)] at each II size Manual - 60 kVp ABC only - minimum kVp provided for 1 mm Al in beam	Live fluoro: Table C-4 Pulse fluoro, cine, spot images should show at least equal resolution as live ABC (NL) image at same II size
		P	Manual or ABC (NL) mode at each II size and large II spot film using digital or mechanical AEC medium setting, as available	Same as acceptance
12.	**Low Contrast Sensitivity**	A	All available output modes [manual, ABC (NL & HLC), pulse, cine, spot (digital & mech.)] at each II size Manual - 85 to 90 kVp, as available ABC only - kVp provided by unit	See at least 3.1 mm test tool holes at 2 % contrast (4 cm Al) (Pulse modes exempt)
		P	Manual or ABC (NL) mode at each II size and large II spot film using digital or mechanical AEC medium setting, as available	Same as acceptance
14.	**Mechanical Spot Film AEC**	A/P	Std: ABC sel or 80 kVp, 1:1 format, 4 cm Al phantom*, AEC = 0 Reproducibility: 3 exposures Max exp time, Pb over all detectors Vary kVp: 70 - 110 by tens Vary thickness: 2 and 4 cm Al** Vary field size: 1:1, 4:1 Vary density: -- to ++, as available	$OD = OD_{BL} \pm 0.15$ (OD_{BL} must be > 1.2) All ≤ ± 5 % of mean Elapsed mAs < 600 $OD = OD_{BL} \pm 0.3$ $OD = OD_{BL} \pm 0.3$ $OD = OD_{BL} \pm 0.1$ Exp dens/exp behavior
13.	**Mechanical Spot Film Alignment**	A/P	Largest II size, 4 cm Al phantom Test all available field size arrangements on single films	No overlapping or shadowing among adjacent spot images

* Alternatively use 15 cm thick acrylic phantom, if available.
** Alternatively use 12, 15, and 18 cm thick acrylic phantom, if available.

Abbreviations: A: acceptance, P: periodic, kV: kilovolt, kVp: kilovolt peak, HVL: half value layer, cm: centimeters, SID: source-to-image distance, OD: optical density, OD_{BL}: optical density baseline, ESE: entrance skin exposure, ABC: automatic brightness control, HLC: High level control, NL: Normal, Al: aluminum, Pb: lead, FOV: field of view, SSD: source-to-skin distance, AEC: automatic exposure control, II: image intensifier, medium setting: mean available technique setting for the given output mode.

Table 4.1: General Fluoroscopic Unit Survey Requirements, Continued

	Test	Freq	Measurements	Tolerance
15a.	**Mechanical Spot Film ESE**	A/P	Largest II, grid in beam, 1:1 format, AEC at neutral density, 4 cm Al* Testing protocols: Programmable: Std/Med abdomen Non-programmable: 80 kVp	A. Establish baseline for film OD ≈ 1.2 P. No sig change from acceptance (± 10 %) (Forward to NEHC)
15b.	**Digital Spot Film ESE**	A/P	Largest II, grid in beam, 4 cm Al* Testing protocols: Programmable: ABC default kVp Non-programmable: 80 kVp	A. Establish baseline after contrast curve set P. No sig change from acceptance (± 10 %) (Forward to NEHC)
16.	**Contrast Response (Digital Systems)**	A	One film at medium output settings for last image hold & digital spot film using largest II size collimated to Al wedge	Reasonable approx of manufacturer's recommendation (Including MO pref.)
		P	Same as acceptance	No sig change from acceptance
17.	**Input Phosphor Exposure Rate (IPER)**	A	Not a routine measurement (Vendor specific set-up)	± 20 % of manuf target setting

* Alternatively use 15 cm thick acrylic phantom, if available.

Abbreviations: A: acceptance, P: periodic, kV: kilovolt, kVp: kilovolt peak, HVL: half value layer, cm: centimeters, SID: source-to-image distance, OD: optical density, ESE: entrance skin exposure, ABC: automatic brightness control, HLC: High level control, NL: Normal, Al: aluminum, Pb: lead, FOV: field of view, SSD: source-to-skin distance, AEC: automatic exposure control, II: image intensifier, medium setting: mean available technique setting for the given output mode.

Chapter 5

Digital Subtraction Angiography (DSA) Units

Minimum Required Personnel Qualifications:

Level III (Advanced Radiological Systems Surveyor)

Testing Periodicity:

All units: Annually, upon acceptance and after major repairs

Instrumentation:

1. Electrometer with small and large ion chambers (6 cm^3 and 180 cm^3 nominal vols).
2. Instrumentation required to test a general fluoroscopic unit.
3. Non-invasive Digital Subtraction Angiography (DSA) phantom as described in reference (1). The phantom should have a base section with an insert slot and the following blocks or inserts:
   a. Blank insert
   b. Step wedge block
   c. Variable bone thickness block
   d. High contrast resolution pattern insert
   e. Low contrast artery insert
   f. Linearity insert
   g. Registration plate
4. 0.1 mm Pb precision test pattern

Introduction:

1. DSA capability among fixed and portable fluoroscopy systems has increased significantly in the last five years. State-of-the-art C-arms routinely provide subtraction and roadmapping.

2. DSA systems should be tested for, and meet all applicable standard fluoroscopy performance requirements prior to being subjected to additional, specialized DSA tests.

References:

1. AAPM Report 15, *Performance Evaluation and Quality Assurance in Digital Subtraction Angiography*, 1985.
2. Code of Federal Regulations, Title 21, Chapter 1, Sections 1020.30, 1020.31, 1020.32; 1 April 1996 edition.
3. Curry, T.S. III, Dowdey J.E., Murry, R.C. Jr. *Christensen's Physics of Diagnostic Radiology*. Lea & Febiger, Philadelphia. 1990.
4. Gray, J.E., Winkler, N.T., Stears, J., Frank, E.D. *Quality Control in Diagnostic Imaging*; University Park Press, Baltimore, 1983.
5. NCRP Report 99. *Quality Assurance for Diagnostic Imaging Equipment*, 1988.
6. *Quality Assurance for Fluoroscopic X-ray Units and Associated Equipment*; Bureau of Radiological Health; Rockville, MD; October 1979.
7. Chakraborty, D.P. and Boone, J.M. *Routine Stray and Scatter Measurements: Environmental Survey*, Medical Physics Monograph No. 20., American Institute of Physics, Woodbury, 1994.

Table 5.1: Digital Subtraction Angiography Unit Survey Requirements

	Test	Freq	Measurements	Tolerance
1.	**High Contrast Resolution**	A	0.1 mm Pb test pattern parallel, perp and at 45° to raster lines. All available output modes at each available II size.	Establish baseline resolutions.
		P	0.1 mm Pb test pattern at 45° to raster lines. Most commonly used output mode and II size.	Maintain acceptable level.
2.	**Low Contrast Performance**	A	Low contrast artery insert perp to raster lines. All available output modes at each II size.	Establish baseline sensitivities.
		P	Most commonly used output mode and II size.	Maintain acceptable level.
3.	**Spatial Uniformity**	A	Same phantom arrangement as Test No. 2. All available output modes at each available II size. Determine thinnest vessel maintaining uniform thickness along its entire length at each contrast concentration.	Establish baseline thicknesses at each concentration.
		P	Most commonly used output mode and II size.	Maintain acceptable level.
4.	**Contrast Linearity**	A	Contrast linearity insert perp to raster lines. All available output modes at each II size. Calculate linear correlation coefficient.	Establish baseline coefficients.
		P	Most commonly used output mode and II size.	± 0.01 of baseline
5.	**Contrast Uniformity**	A	Phantom base + plastic step wedge or bone block. Low contrast artery insert perp to raster lines and step wedge step or bone block All available output modes at each II size. Determine thicknesses of bone or plastic wedge under which the thickest vessel at each contrast concentration is visible.	Establish baselines for tissue and bone.
		P	Most commonly used output mode and II size.	Maintain acceptable levels.
6.	**Subtraction Artifact Evaluation**	A	Registration plate on top of phantom base. All available output modes at largest II size. Determine minimum subtraction artifact development time.	Establish baseline times.
		P	Most commonly used output mode at largest II size.	Maintain acceptable time.
7.	**Entrance Exposure Rates**	A	Full DSA phantom (base + folded ramp). All available output modes at each II size. 6 cm^3 ion chamber at phantom surface.	Establish baseline dose rates.
		P	Most commonly used output mode and II size.	± 20% of baseline
8.	**Scatter Exposure Rates**	A	Full DSA phantom (base + folded ramp). All available output modes at each II size. 180 cm^3 ion chamber at room locations occupied by angiography staff.	Establish baseline dose rates.
		P	Most commonly used output mode and II size.	± 20% of baseline

Abbreviations: A: acceptance, P: periodic, II: image intensifier

Chapter 6

Linear Tomographic Units

Introduction

1. Conventional tomography is used in cases where anatomical information is desired in a specific plane of interest. Through the motion of the x-ray tube and the film cassette about a fulcrum, structures not in the object plane are blurred more than those in the plane of interest. Examples of tomography include: inner ear, cervical spine and long bone fractures.

2. The instructions in appendix E are based on the most commonly found type of tomography used, *linear motion tomography*. The performance characteristics that are considered will be appropriate for all the types of tomography motions (linear, curvilinear, circular, elliptical, spiral, hypocycloidal).

Minimum Required Personnel Qualifications:

Level II (Intermediate Radiological Systems Surveyor)

Testing Periodicity:

All units: Annually, upon acceptance and after major repairs.

Instrumentation:

Tomographic Test Phantom kit that includes test devices for location of plane thickness of cut, exposure uniformity and beam path. Examples of commercial units: RMI tomographic test tool model 132 or Nuclear Associates tomographic phantom model 76-400.

References:

1. AAPM Report 31, *Standardized Methods for Measuring Diagnostic X-ray Exposures*. 1990.
2. Code of Federal Regulations, Title 10, Chapter 1, Parts 1000.55(c)(3)(f)(1), Part 1000.35(c)(3)(f)(1).
3. Code of Federal Regulations, Title 21, Chapter 1, Parts 1020.30, 1020.31, 1020.32; 3 May 1993 edition.
4. Curry, T.S. III, Dowdey J.E., Murry, R.C. Jr. *Christensen's Physics of Diagnostic Radiology*. Lea & Febiger, Philadelphia. 1990.
5. Gray, J.E., Winkler, N.T., Stears, J., Frank, E.D. *Quality Control in Diagnostic Imaging*; University Park Press, Baltimore, 1983
6. NCRP Report 99. *Quality Assurance for Diagnostic Imaging Equipment*, 1988
7. *Quality Assurance for Conventional Tomographic X-Ray Units*, HEW Publication (FDA) #80-8096, October 1979.

Table 6.1: Linear Tomographic Unit Survey Requirements

	Test	Frequency	Measurements	Tolerance
1	**Location of Cut Plane**	A/P	Measure at 1,3,5,7 cm	3.0 mm from indicated plane
2	**Angle of Cut**	A/P	(A)All angles available, (P)all clinically used angles	± 5 degrees > 30 degrees
3	**Thickness of Cut**	A/P	(A) min to max in 1 cm increment, (P) clinically used thicknesses	NA
4	**Flatness of Plane**	A/P	Uniform display of reoccuring pattern (e.g. mesh) across field of view	No more than 3 mm distortion of any area of the field of view for 40 mesh (1.6 mm holes)
5.	**Exposure Uniformity**	A	Make travel motion with exposure technique to produce density of 1.0 OD	No more than 0.3 OD difference in the line density, some density variation allowed.
		P	Most commonly used motions	
6.	**Resolution in Plane**	A/P	See manual	>30 mesh (1.2 mm holes)
7.	**ESE**	A/P	Angle > 30 degrees Fulcrum at 7 cm IC at fulcrum, 80 kVp	Track data Send to NEHC

Abbreviations: A: acceptance, P: periodic, kVp: kilovolt peak, cm: centimeters, SID: source-to-image distance, ESE: entrance skin exposureAl: aluminum, IC: ion chamber.

Chapter 7

Computerized Tomographic Units

Introduction

1. X-ray computerized tomographic (CT) scanners represent a departure from conventional film/screen x-ray performance. CT scanners generate a thin, well collimated beam of x-rays to a cross section of the patient's body from multiple rotational angles. The transmitted beam is collected by radiation detectors, and the information is fed into a computer which analyzes the data and constructs an image which reflects variations of the physical attenuation characteristics of the material.

2. The CT is unique in its ability to detect exceptionally fine variations in linear attenuation of adjacent structures and incorporate these differences into a diagnostic quality image suitable for further use in radiation therapy treatment planning and stereotactic surgical navigation.

3. Due to the potential complexity of CT scanner operation, a radiological technologist, trained and experienced on the CT scanner being evaluated should be present during testing. The technologist should operate the scanner while the physicist performs the tests.

Minimum Required Personnel Qualifications:

Level II (Intermediate Radiological Systems Surveyor)

Testing Periodicity:

All units: Annually, upon acceptance and after major repairs

Instrumentation:

1. Electrometer with 10 cm CT and large (180 cc) volume ion chambers
2. Manufacturer's QC Phantoms
3. AAPM performance phantom with the following inserts:
   a. Low contrast
   b. High contrast and MTF wire
   c. Linearity pegs
   d. Aluminum ramps
   e. Spiral insert
4. CTDI phantoms (16 cm diameter head and 32 cm diameter body)
5. Tape measure, 10 - 20 cm ruler (marked in mm)
6. Bubble level
7. Therapy localization film (TL) with 1 cm acrylic backing plate
8. 8X Optical Comparitor
9. Densitometer
10. Type 1100 10 x 10 cm Aluminum plates (varying thicknesses)
11. Adhesive tape
12. Paper clips
13. Sharp pin
14. CT compatible kVp meter

References:

1. AAPM Report 1, *Phantoms for Performance Evaluation and Quality of CT Scanners*, 1977.
2. AAPM Report 39, *Specification and Acceptance Testing of Computed Tomography Scanners*, May 1993.
3. Code of Federal Regulations, Title 21, Chapter 1, Part 1020.30, 1020.31, 1020.32; 1 April 1996 edition
4. Curry, T.S. III, Dowdey J.E., Murry, R.C. Jr. 1990. *Christensen's Physics of Diagnostic Radiology*. Lea & Febiger, Philadelphia.
5. Gray, J.E., Winkler, N.T., Stears, J., Frank, E.D. *Quality Control in Diagnostic Imaging*; University Park Press, Baltimore, 1983

Table 7.1: Computerized Tomography Unit Survey Requirements

	Test	Frequency	Measurements	Tolerance
1.	**Table Loading**	A	Loaded, maximum and minimum height, in & out	Manufacturer’s specifications
2.	**Laser Light Alignment**	A	Difference between radiation slice and laser light (external & internal)	± 2 mm
3.	**Table Positioning**	A	Slice, return to same position, same slice Smallest slice available	± 1 mm
4.	**Table Incrementation**	A P	Each slice thickness 5 mm slice thickness on 5 mm centers	± 1mm
5.	**Table, Gantry Alignment**	A	Centers: Table and gantry	± 5 mm
6.	**Gantry Tilt Angle**	A	Extreme left, extreme right, zero	± 3^{o} of nominal setting
7.	**Exposure Slice Width**	A P	All slice widths Minimum , maximum and 2 in between	± 1 mm at nominal width
8.	**Projection Scan Accuracy**	A/P	Smallest slice thickness on solder wire	Wire and artifact visible
9.	**Noise**	A/P	Largest Slice thickness High resolution and NL head & body FOV, 1000 mm^2 ROI	≤ 35 HU HR ≤ 4 HU NL
10.	**Uniformity**	A/P	Largest slice thickness 5 ROI’s at 1000 mm^2 Center and 4 quadrants in center 70% of field	± 5 HU (AAPM) ± 2 HU (target)
11.	**CT # Calibration**	A/P	Air and water phantom, same conditions as test #10	Water: 0 ± 1.5 HU Air: 1000 ± 3 HU Different algorithms: ± 3 HU
12.	**Linearity**	A/P	Largest slice thickness ROI over multiple material pegs, head & body FOVs	R ≥ 0.994 (Linear correlation coefficient)

Abbreviations: A: acceptance, P: periodic, HU: Hounsfield units, NL: Normal, FOV: field of vision, ROI: region of interest, DPSC: Defense Personnel Support Center, MTF: Modulation transfer function, Rad: radiation absorbed dose (1 rad = 100 erg/g), MSAD: Multiple scan average dose, CTDI: Computed tomography dose index, mR: millirad = 1/1000 rad, kV: kilovolt, SMPTE: Society of Motion Picture and Television Engineers

Table 7.1: Computerized Tomography Unit Survey Requirements Continued

	Test	Frequency	Measurements	Tolerance
13.	**Contrast Scale**	A/P	1000 mm^2 ROIs at field center, body FOV Air and Water targets	Manuf. specs. Track over time
14.	**Low Contrast Sensitivity**	A/P	Largest slice thickness, all algorithms Head and body FOVs	DPSC or manufacturer's specifications
15.	**High Contrast Resolution**	A/P	Largest slice thickness, all algorithms Head and body FOVs Plus insert and bars	1.0 mm std head &body algorithms 0.5 mm high resolution algorithm
16.	**MTF**	A	Largest thickness, all algorithms Head and body FOVs	Resolution at 10-50% MTF levels (DPSC or manufacturer's specifications)
17.	**Slice Sensitivity**	A	All thicknesses	± 1 mm at nominal slice thickness Thickness = 4 -10 mm
		P	minimum, maximum plus 2 in between	
18.	**Surface Dose by Film Dosimetry**	A	All slice thicknesses Single and multiple (5) slice groups	≤ 4 rads for single slice Multislice dose < 1.5 single slice dose for slice ≥ 3 mm
19.	**Scatter**	A/P	Largest slice thickness Body FOV, std body algorithm CTDI Body Phantom simulating patient, measure @ occupied locations	< 100 mR/yr to the public in occupied spaces
20.	**Radiation Protection and Safety**	A/P	Checklist	

Abbreviations: A: acceptance, P: periodic, HU: Hounsfield units, NL: Normal, FOV: field of vision, ROI: region of interest, DPSC: Defense Personnel Support Center, MTF: Modulation transfer function, Rad: radiation absorbed dose (1 rad = 100 erg/g), MSAD: Multiple scan average dose, CTDI: Computed tomography dose index, mR: millirad = 1/1000 rad, kV: kilovolt, SMPTE: Society of Motion Picture and Television Engineers

Table 7.1: Computerized Tomography Unit Survey Requirements Continued

	Test	Frequency	Measurements	Tolerance
21.	**MSAD (formerly CTD1)**	A	Standard technique. Head and body FOV, all slice thicknesses, appropriate phantom Head Phantom with body technique	± 20 % manufacturer's CTD1 for slice thickness > 3 mm or manufacturer's specifications if available
		P	Head phantom: std head and body techniques 10 mm slice thickness	± 20 % of baseline values
22.	**Beam Quality**	A	Default kV	NA
23.	**Hard Copy Output Device**	A	SMPTE pattern if available or other available test pattern Visual: High contrast, low contrast comparison of monitor and film images	Contrast and resolution: Hard copy and monitor images are visually equivalent
		P	Low contrast and std clinical settings	

Abbreviations: A: acceptance, P: periodic, HU: Hounsfield units, NL: Normal, FOV: field of vision, ROI: region of interest, DPSC: Defense Personnel Support Center, MTF: Modulation transfer function, Rad: radiation absorbed dose (1 rad = 100 erg/g), MSAD: Multiple scan average dose, CTDI: Computed tomography dose index, mR: millirad = 1/1000 rad, kV: kilovolt, SMPTE: Society of Motion Picture and Television Engineers

Chapter 8

Mammographic Units

Introduction:

The Mammography Quality Standards; Correction; Final Rule, 21 CFR Parts 16 and 900, November 10, 1997, requires any facility that produces, processes or interprets mammograms to be certified by the Food and Drug Administration (FDA). To be certified, facilities must meet the federal regulations and must be accredited by a FDA-approved private or state accrediting body.

Minimum Required Personnel Qualifications:

Level II (Intermediate Radiological Systems Surveyor) and Level III (Advanced Radiological Systems Surveyor) with additional qualifications as specified by MQSA.

Testing Periodicity:

All units: Annually, upon acceptance and after major repair.

Instrumentation: As specified by the MQSA.

References:

1. Code of Federal Regulations, Title 21, Chapter 1, Parts 1020.30, 1020.31, 1020.32; 3 May 1993 edition.
2. Curry, T.S. III, Dowdey J.E., Murry, R.C. Jr. 1990. *Christensen's Physics of Diagnostic Radiology*. Lea & Febiger, Philadelphia.
3. Gray, J.E., Winkler, N.T., Stears, J., Frank, E.D. *Quality Control in Diagnostic Imaging*; University Park Press, Baltimore, 1983.
4. Mammography Quality Standards Act (MQSA) of 1992.
5. *Quality Assurance in Mammography*. American College of Radiology (ACR), 1994.

Chapter 9

Ultrasound Scanner

Introduction:

1. There currently exist only *recommendations* for QC programs for ultrasound [1-3]. However, such programs are important for ensuring the accuracy of patient examinations as well as for controlling repair and maintenance costs of the units themselves.

2. The tests listed in Table 9.1 should be performed using a general purpose transducer with time gain compensation (TGC) and depth settings as described in ref. 2.

Minimum Required Personnel Qualifications:

Level II (Intermediate Radiological Systems Surveyor)

Testing Periodicity:

All units: Annually, upon acceptance and after major repairs.

Instrumentation:

1. Tissue equivalent phantom with average velocity of sound of 1540 m/s ± 0.05 % and an attenuation coefficient of 0.5 to 0.7 dB/MHz·cm.

References:

1. Hendrick, W.R., and Hykes, D.L. 1997 *Journal of Diagnostic Medical Sonography*: 13, pp 68-75.
2. Carson, P.L. and Zagzebski, J.A. 1981. *Pulse Echo Ultrasound Imaging Systems Performance Tests and Criteria*; AAPM Report No 8, American Institute of Physics.
3. Poznanski, A.K. 1988. *Quality Assurance for Diagnostic Imaging*; NCRP Report No. 99, National Council on Radiation Protection.

Table 9.1: Ultrasound Scanner Survey Requirements

	Test	Frequency	Measurements	Tolerance
1.	**Geometric Accuracy**	M	Measure the predetermined spacing of reflecting rods in the ultrasound phantom.	Vertical Measurements ± 1% Horiz. Measurements ± 3%
2.	**Transducer Sensitivity**	M	Check for smooth variation as a function of depth in the attenuated pattern of reflections.	Sat/Unsat.
3.	**Dead Zone/Max Depth**	M	Measure the dead zone and maximum depth visualized.	Neither reading should vary by more than 10% from the previous survey reading.
4.	**General Maintenance**	M	Check for loose connections, frayed cables, and clean air filters. Verify that the unit is positioned to allow proper ventilation.	Sat/Unsat
5.	**Image Output Check**	M	Print and evaluate a SMPTE image from the laser imager. Speak with techs about artifact problems.	Sat/Unsat
6.	**High Contrast Spatial Resolution**	Q	Determine which of the closely spaced reflectors in the phantom can be resolved in the axial and lateral directions.	Both readings should agree with that from the previous survey or be the next adjacent reflector available.
7.	**Focal Depth Determination**	Q	Verify that the focal depth setting agrees with the depth of the narrowest observed reflector.	Sat/Unsat.
8.	**Low Contrast Spatial Resolution**	Q	Record the smallest low contrast cyst visible in the phantom for at least two depths	Both readings should agree with that from the previous survey or be the next adjacent cyst available.

Abbreviations: M: monthly, Q: quarterly, SMPTE: Society of Motion Picture and Television Engineers.

Chapter 10

Magnetic Resonance Imaging Units

Minimum Required Personnel Qualifications:

Level III (Advanced Radiological Systems Surveyor)

Testing Periodicity:

All units: Annually, upon acceptance and acceptance & after major repairs

Instrumentation:

1. Static magnetic field meter (Gauss meter)
2. Assorted single or multi-purpose phantoms provided by the MRI manufacturer or a third party vendor for image quality and artifact assessment. The final phantom inventory should be determined during installation planning and acceptance.

Testing Parameters:

Testing parameters and procedures are likely to be unit specific and should be determined during installation and acceptance. Periodic testing should address at the least the following parameters:

a. Resonance frequency
b. B_0 homogeneity
c. Signal to noise ratio
d. Image uniformity
e. Spatial linearity and resolution
f. Slice thickness, position, and separation
g. Phase related image artifacts
h. Laser hard copy image quality

References:

1. AAPM Report 20. *Site Planning for Magnetic Resonance Imaging Systems*, 1987.
2. AAPM Report 28. *Quality Assurance Methods and Phantoms for Magnetic Resonance Imaging*, 1990.
3. AAPM Report 34. *Acceptance Testing of Magnetic Resonance Imaging Systems*, 1992.
4. ACMP Report 5. *Radiation Control and Quality Assurance Surveys: Magnetic Resonance Imaging, A Suggested Protocol*, 1989.
5. NCRP Report 99. *Quality Assurance for Diagnostic Imaging Equipment*, 1988.
6. Sprawls, P. and Bronskill, M.J. (eds), *The Physics of Magnetic Resonance Imaging*, 1992 AAPM Summer School Proceedings, 1992.
7. Dixon, R.L. (ed), *MRI: Acceptance Testing and Quality Control; The Role of the Clinical Medical Physicist*, 1988 AAPM Summer School Proceedings, 1988.
8. International Non-Ionizing Radiation Committee of the International Radiation Protection Association, *Protection of the patient undergoing a magnetic resonance examination*, Health Physics, Vol. 61 (6), 1991.
9. Tenforde, T. S. and Budinger, T. F., *Biological effects and physical safety aspects of NMR imaging and in vivo spectroscopy*, Medical Physics Monograph 14, 1986.

Chapter 11

Nuclear Medicine Imaging Quality Control

(Under Construction)

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Chapter 12

Linear Accelerators

Minimum Required Personnel Qualifications:

Each Navy radiation oncology department shall establish local qualification standards for personnel performing these evaluations.

Testing Periodicity:

As specified in reference 1.

Instrumentation:

As specified in reference 1.

References:

1. G. J. Kutcher, L. Coia, and M. Gillin, "*Comprehensive QA for Radiation Oncology: Report of AAPM Radiation Therapy Committee Task Group 40,*" Med. Phys. 21(4)(1994).

Chapter 13

Film Processor and Darkroom Quality Control

Introduction

1. This chapter and appendix G are to be used as guides by the medical physicist when reviewing processor and darkroom quality control programs.

2. Film processing has a major effect on several aspects of medical imaging including image contrast, image quality, film speed, and artifact production. Film processing can contribute to delays in image availability, loss of image quality, unnecessary patient exposure, reduced productivity, increased costs, and environmental contamination.

3. The introduction of automatic processing has allowed radiology departments to standardize techniques. This standardization resulted in a reduction of retakes and consequently patient dose as well as a reduction in the patient waiting time.

4. Unfortunately, quality control of automatic processors has not always received the attention necessary to maintain film processing at optimal levels.[1] Studies have shown that there has been a downward trend in the quality of processed films over the past fifteen years, due largely to a lack of appropriate quality control (QC). As an aside, it is noteworthy that mammography processor QC has improved over the same time period, due largely to Federal and American College of Radiology guidelines, which has resulted in tighter processor QC and improved image quality.

5. The medical physicist has many responsibilities in the quality assurance program of a Radiology department. The medical physicist serves as a consultant to radiologists, technologists, service engineers and administrative personnel.

6. Included in the medical physicist's responsibilities:

   a. Monitors processor QC, including periodic review of QC charts and logs.

   b. Assists in the selection of appropriate screen film combinations, photographic chemistry, developer temperature, and development time.

   c. Assists in the selection of storage areas for photosensitive materials.

   d. Participates in the acceptance testing of photographic processors.

7. Every physicist should carry out processor QC on several processors for at least a month. This will provide insight into the problems associated with processor QC as well as an awareness of the time and effort involved for the processor technician.

8. In order to evaluate these areas, it is necessary to know what is performed. The processor quality assurance program includes preventive maintenance, quality control tests, and silver recovery. For the medical physicist, it should be noted that silver is the principal byproduct of film processing. If the silver recovery process is not completely efficient, unrecovered silver will pass into the environment through the waste water system. Refer to local command instructions for the silver recovery programs.

Minimum Required Personnel Qualifications:

Level 1 (Basic X-ray Surveyor)

Testing Periodicity:

Annually

Instrumentation:

1. Sensitometer
2. Densitometer and calibration strip
3. Folder
4. Penetrometer (step wedge)
5. Digital thermometer
6. Fixer retention test kit
7. Silver test kit
8. Light meter

References:

1. *Kodak Processor Quality Control Manual* Eastman Kodak Company, Health Sciences Division, Rochester, NY.
2. *Nationwide Evaluation of X-Ray Trends (NEXT),* Conference of Radiation Control Program Directors, Inc. (CRCPD). Frankfort: (current version).
3. *Quality Control for Mammography, Kodak Min-R QC Program,* Eastman Kodak Company, Health Sciences Division, Rochester, NY.
4. Suleiman, O.H., *Results of Federal and State Studies on Film Processing*," in Film Processing in Medical Imaging, A. G. Haus, ed., Medical Physics Publishing, Madison, WI. 1993.
5. William E. J., McKinney, J. B. *Radiographic Processing and Quality Control*, Lippincott Company, Philadelphia, 1988.

Table 13.1: Processor and Darkroom Quality Control

	Test	Frequency	Measurements	Tolerance
1.	**Sensitometric Testing Evaluation Program (STEP)**	P	CDRH Procedure	± 20 % Submit to NEHC
2.	**Visual Inspection of Processor**	P	Visual	
3.	**Darkroom Ventilation**	P	Sniff test If excessive, use industrial hygiene services for direct measurement	10 air changes per hour
4.	**Darkroom Cleanliness**	P	Visual inspection- cleanliness and no miscellaneous storage	No dirt No misc storage
5.	**Plumbing and Water Filtration**	P	Visual Inspection: drains, filters and hoses	Unobstructed drain, filtered water and easy accessability
6.	**Film Storage**	P	Temperature, humidity, location Visual Film Storage	Comfort Vertical Storage of all film
7.	**Darkroom Fog Test**	P	2 minute exposure of film with step wedge	Change in OD ≤ 0.02 with OD of 1.2 - 14
8.	**Light Leaks**	P	Visual inspection with all safe lights off	None
9.	**Last Safelight Filter Check**	P	Records check	≤ 24 months
10.	**Appropriate Safelight Use**	P	Distance of safelight from working surfaces, bulb strength (Watts), Filter Wavelength	What is appropriate and Manufacturer's recommended
11.	**Film Cassettes clean and in good condition**	P	Visually inspect 20% of cassettes	No gross deformities
12.	**Film Screen Cleanliness**	P	Visually inspect 2 cassettes of each size	No dirt or scratches
13.	**Screen-film contact test**	P	Administrative review of records and films	Every 6 months
14.	**Viewbox Cleanliness[1]**	P	Visual inspection	No obvious marks on viewbox
15.	**Viewbox Light Uniformity[1]**	P	4 quadrants - use mean light meter reading at 1 cm within and among panels in a single electrical unit	if ± 20 %, replace lamps

Abbreviations: P: periodic, OD: optical density, cm: centimeters, cd: candella.
[1]Viewboxes where diagnosis is made, reading rooms, teaching areas and clinical use only.

Table 13.1: Processor and Darkroom Quality Control continued

	Test	Frequency	Measurements	Tolerance
16.	**Viewbox Light Color**[1]	P	Visual inspection	All should appear nearly the same and light should be nearly white
17.	**Viewbox Luminance**[1]	P	Average of light meter readings at 1 cm	> 1000 nits (cd/m^2)

Abbreviations: P: periodic, OD: optical density, cm: centimeters, cd: candella

[1]Viewboxes where diagnosis is made, reading rooms, teaching areas and clinical use only.

Chapter 14

Repeat Rate Analysis

Introduction

1. Repeat rate analysis consists of the measure of the number of films which were discarded during a time period (usually a month) as well as the total number of films justified by the studies ordered, the assignment of a technical reason for the discard of each film and the calculation of the percentage of unsatisfactory films.

2. The analysis of repeat rates is an important component of a complete quality control program. This program provides accountability and a mechanism for identifying specific areas for improvement which may be addressed through in-service training needs or additional quality control measures. The goal is to reduce the number of repeat films as low as possible.

3. The reduction of repeat rates has professional, ethical, biological and economical benefits.[1] Most government agencies have repeat analysis programs. Studies have shown that in hospitals where no repeat rate analysis program exists, most repeats are caused by poor technical quality of the radiograph, but where a program is used, most repeats are from positioning errors. [2,3]

Minimum Required Personnel Qualifications:

Level I (Basic X-ray Surveyor)

Testing Periodicity:

Annually

Instrumentation:

None required

Procedures:

See appendix H.

Reporting Requirements:

Report overall repeat rate of each facility major work center back to facility with summary to NEHC.

References:

1. Carrol, Q. B., *Fuch's Principles of Radiographic Exposure and Quality Control*, Fourth Edition, Charles C. Thomas, 1990.
2. *Nationwide Evaluation of X-Ray Trends (NEXT)*, Conference of Radiation Control Program Directors, Inc. (CRCPD). Frankfort: CRCPD (current version)
3. Suleiman, O.H., *Results of Federal and State Studies on Film Processing*, in Film Processing in Medical Imaging, A. G. Haus, ed., Medical Physics Publishing, Madison, WI. 1993.

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Chapter 15

Entrance Skin Exposure

Introduction:

One of the largest contributors to total population radiation exposure from man-made radiation sources is from diagnostic (dental and medical) radiography. One of the goals of the Conference of Radiation Control Program Directors (CRCPD) is to reduce the unnecessary component of dental and medical x-ray exposure to a level as low as reasonably achievable (ALARA)[2].

Reference 2 lists recommended patient exposure guides which reflect "State of current practice" in a cross section of radiography facilities across the United States. They are to be used as a tool for reducing unnecessary radiation exposure to patients, while maintaining or improving image quality. Calculated Entrance Skin Exposures (ESE) should be compared to these average values.

Exposures that significantly exceed the levels indicated in the guides for routine examinations are likely to represent unnecessary patient doses and causes for such excessive exposure should be investigated. A reasonable but arbitrary range of acceptability is ± 20% of a guide value.

Minimum Required Personnel Qualifications:

Qualifications appropriate for type of equipment.

Testing Periodicity:

In conjunction with each x-ray survey.

Instrumentation:

1. ion chamber
2. electrometer
3. phantom
4. tape measure
5. 5 1.0mm copper sheets, 20 x 20 cm
6. Optional: CDRH test stand

References:

1. AAPM Report 31. *Standardized Methods for Measuring Diagnostic X-Ray Exposures*, 1990.

2. *Average Patient Exposure/Dose Guides. A report by Committee n Quality Assurance in Diagnostic Radiology (H-7).* Conference of Radiation Control Program Directors, Inc. CRCPD Publication 92-4, 1992.

2. *Nationwide Evaluation of X-Ray Trends (NEXT)*, Conference of Radiation Control Program Directors, Inc. Frankfort: CRCPD. 1974 – 1994.

Chapter 16

Radiation Shielding Design and Evaluation for Medical and Dental X-Ray Facilities

Introduction:

The National Council on Radiation Protection and Measurements (NCRP) Report No. 116[1] has recommended that the effective dose to a given member of the general public not exceed 100 mrem (10 mSv) per year from man-made sources. This value has been adopted by the U.S. Navy and many states as a regulatory limit. Appendix J provides a set of reasonable parameters to use for shielding design for various types of x-ray facilities. Practical examples are provided for typical facilities; including, a dental suite, radiographic suite, fluoroscopic suite, and mammographic suite.

Minimum Required Personnel Qualifications:

Level II (Intermediate X-ray Surveyor)

Design and Evaluation Periodicity:

All new radiographic installations and after any major renovation to existing facilities. This chapter does not provide information to evaluate high energy radiation therapy facilities.

Instrumentation:

1. Electrometer with large ion chamber (180 cm^3 nominal volume)

References:

1. National Council on Radiation Protection and Measurements. Limitations of exposure to ionizing radiations. Bethesda, MD: NCRP; Report No. 116; 1993.
2. National Council on Radiation Protection and Measurements. Structual shielding design and evaluation for medical use of x-rays and gamma rays of energies up to 10 MeV. Bethesda, MD: NCRP; Report No. 49; 1976.
3. Simpkin DJ: Evaluation of NCRP report 49 assumptions and use factors in diagnostic radiology facilities. Med Physics 23:577-584; 1996
4. Dixon RL: On the primary barrier in diagnostic x-ray shielding. Med Physics 21: 1785-1794; 1994.
5. Archer BR, Fewell TR, Conway BJ, and Quinn PW: Attenuation properties of diagnostic x-ray shielding materials. Med Physics 21: 1499-1507; 1994.
6. Simpkin DJ: Shielding requirements for mammography. Health Phys. 53:267-179; 1987.
7. Simplin DJ: Transmission data for shielding diagnostic x-ray facilities. Health Phys. 68:704-709; 1995.
8. Suleiman OH, Conway BJ, Fewell TR, Slayton RJ, Rueter FG, and Gray J: Radiation Protection requirements for medical x-ray film. Med. Physics 22:1691-1693; 1995.
9. Dixon, RL and Simpkin DJ: Application of new concepts for radiation shielding of medical diagnostic x-ray facilities. RSNA 1998.

Appendix A

X-Ray Surveyor Qualification Levels

Level	Qualified Units
I. *Basic X -Ray Surveyor*	A. General radiographic units B. Dental radiographic units C. General fluoroscopic units D. Evaluation of quality control programs
II. *Intermediate Radiological Systems Surveyor*	A. Fluoroscopic c-arm units B. Urologic units C. Tomographic units D. Computed tomographic unit surveys E. Ultrasound scanner surveys F. Nuclear medicine imaging system quality control G. Establishment of quality control programs
III. *Advanced Radiological Systems Surveyor*	A. Computerized tomographic unit acceptance testing B. Advanced x-ray systems including interventional, angiographic, DSA and cardiac catheterization C. Magnetic resonance imaging (MRI) system surveys and acceptance testing D. Ultrasound scanner acceptance testing E. Nuclear medicine imaging system acceptance testing F. Mammographic unit surveys and acceptance testing

1. Surveyors shall be fully qualified at Level I before progressing to Level II.
2. Surveyors shall be fully qualified for all systems included in qualification levels I and II before being approved as a surveyor at those levels.
3. Surveyors may be qualified for sublevels (individual systems) within Level III.

APPLICATION FOR QUALIFICATION AS NAVY X-RAY SURVEYOR

Name, grade and branch ____

Current phone ____

Current E-mail address ____

Board or state certifications ____

SURVEY EXPERIENCE

ASSIGNMENTS	APPROXIMATE NUMBER OF SURVEYS OF EACH TYPE CONDUCTED																
Command and years assigned	I A	I B	I C	I D	2 A	2 B	2 C	2 D	2 E	2 F	2 G	3 A	3 B	3 C	3 D	3 E	3 F
Mentor signature:	Mentor signature verifies that surveyor applicant is proficient in evaluating the types of equipment for which numbers are listed above.																
Mentor signature:	Mentor signature verifies that surveyor applicant is proficient in evaluating the types of equipment for which numbers are listed above.																
Mentor signature:	Mentor signature verifies that surveyor applicant is proficient in evaluating the types of equipment for which numbers are listed above.																

I.
Basic X-Ray Surveyor

A. General radiographic units
B. Dental radiographic units
C. General fluoroscopic units
D. Evaluation of quality control programs

II.
Intermediate
Radiological Systems Surveyor

A. Fluoroscopic c-arm units
B. Urologic units
C. Tomographic units
D. Computed tomographic unit surveys
E. Ultrasound scanner surveys
F. Nuclear medicine imaging system quality control
G. Establishment of quality control programs

III.
Advanced
Radiological Systems Surveyor

A. Computerized tomographic unit acceptance testing
B. Advanced x-ray systems including interventional, angiographic, DSA and cardiac catheterization surveys and acceptance testing
C. Magnetic resonance imaging (MRI) system surveys and acceptance testing
D. Ultrasound scanner acceptance testing
E. Nuclear medicine imaging system acceptance testing
F. Mammographic unit surveys and acceptance testing

RECORD OF CONTINUING EDUCATION

Name of training course	Sponsoring organization	Location of course	Dates of course	# of hours

Revised 5/2/01

Appendix B

Performance Tests for General Radiographic Units
Fixed and Portable

A. General Requirements for Radiographic Equipment

1. ***Radiation Exposure Reproducibility***

a. Purpose: To ensure that exposure received for the same mA, time, and kVp is the same from exposure to exposure.

b. Regulations: Determination of reproducibility shall be based on 10 consecutive measurements within a time period of one hour, using the same technique factors. For any specific combination of selected technique factors, the estimated coefficient of variation of radiation exposure shall be no greater than 0.05. (21CFR Ch 1 1020.31 (b)(1))

The coefficient of variation is the ratio of the standard deviation to the mean value of a population of observations. (21 CFR Ch 1 1020.30 (b)(3))

$$C = \frac{s}{\overline{X}} = \frac{1}{\overline{X}}\left[\sum_{i-1}^{n} \frac{(X_i - \overline{X})^2}{n-1}\right]^{1/2}$$

s = Estimated standard deviation of the population
X = Mean value of observations in sample.
X_i = ith observation sampled.
n = Number of observations sampled.

c. Equipment: Electrometer with small ion chamber.

d. Procedure: Set the x-ray tube at 40 inches source-to-table distance, if possible. Place the center of the ion chamber 4 inches above the x-ray table top and center the chamber in the light field. Determine the distance from the focal spot to the center of the ion chamber. Collimate the light field to a narrow beam geometry (e.g. 4x4 cm field) to include the ion chamber. Make radiation exposures at the selected technique. For efficiency, the evaluator is reminded that some meters will read out both exposure and time, therefore, record both for future measurements.

e. Interpretation of results: If the coefficients of variation deviate from the criteria in Table 2.1 consult a qualified service engineer. Exposure reproducibility is critical as it directly influences image quality and patient dose.

2. ***Timer Reproducibility***

a. Purpose: To ensure that the x-ray generator is producing exposure times that are the same from exposure to exposure.

b. Regulations: Determination of reproducibility shall be based on 10 consecutive measurements within a time period of one hour, using the same technique factors. For any specific combination of selected technique factors, the estimated coefficient of variation of radiation exposure shall be no greater than 0.05.

c. Equipment: Exposure timer or exposure meter with timer combination.

d. Procedure: Utilize the procedure described for reproducibility measurements. Measure and record the actual exposure time for 10 exposures at the same timer setting (e.g. 100 msec).

e. Interpretation of results: If the coefficients of variation deviate from the criteria in Table 2.1 consult a qualified service engineer. Timer reproducibility is critical as it directly influences image quality and patient dose.

3. ***Timer Accuracy***

a. Purpose: To ensure that the x-ray generator is producing the exposure time as set on the control panel.

b. Regulations: The accuracy of the timer should be within ±10% of the selected timer setting or ±1 ms for exposure times less than 10ms or 1 pulse for exposure times less than 10 pulses.

c. Equipment: Exposure timer or

exposure meter with timer combination.

d. Procedure: Utilize the procedure described for reproducibility measurements. Measure and record the full range of clinically useful exposure times.

e. Interpretation of results: Refer units deviating from the criteria in Table 2.1 for adjustment by a qualified service engineer. Timer accuracy is critical as it directly influences image quality and patient dose.

4. ***Linearity of mA/mAs***

a. Purpose: To ensure that similar exposures are obtained for the same mAs and kVp regardless of the exposure time and mA used.

b. Regulations: The average ratios of exposure to the indicated mAs product (mR/mAs) obtained at any two consecutive tube current settings shall not differ by more than 0.10 times their sum.

$$(X1-X2) \leq 0.10(X1+X2)$$

where X1 and X2 are the average mR/mAs values obtained at each of two consecutive tube current settings. (21 CFR ch 1, 1020.31(c))

c. Equipment: Electrometer with small ion chamber and timer (or combination unit).

d. Procedure: Utilize the setup described for reproducibility measurements. Measure and record the exposures at 5 different mA settings while keeping kVp and time constant. With some x-ray units, the mA cannot be varied without varying time. In this instance mA must be constant and time varied. Divide the mR output by mAs setting, record mR/mAs as calculated.

e. Interpretation of results: If each of the average ratios between mA stations deviate from the criteria in Table 2.1 consult a qualified service engineer. Linearity of mA/mAs is critical as it directly influences image quality and patient dose.

5. ***Kilovoltage Accuracy***

a. Purpose: To ensure that the x-ray generator is producing the kVp as indicated on the control panel.

b. Regulations: The accuracy must be ± 5 % of the nominal control panel setting or within manufacture specifications.

c. Equipment: kVp meter.

d. Procedure: Place the kVp meter on the x-ray table top. Set the distance from the focal spot to the table top as indicated in the kVp meter owners manual. Collimate the beam to the active area of the kVp meter. Set the desired starting kVp, mA, and time stations on the generator using the manufacture's suggested techniques. Evaluate kVp settings from 50 kV up to the maximum kV incrementing by 5 kV. During periodic evaluation it may be necessary to evaluate only kVp settings from 60 kV to the maximum kV incrementing by 20 kV unless further measurements are necessary. Make an exposure and record the display value of the kVp meter.

e. Possible Pitfalls:

(1) The HVL should always be measured after assuring the kVp is correct.

(2) The major cause of kVp variation is calibration. Some generators maintain their calibration well and others drift constantly. It is important to note that a change in kVp may not always show as a change in film density because changes in the mA will often compensate for the change in kVp.

(3) Since the kVp affects the radiographic contrast, it must be checked to assure that it is acceptable.

(4) Other major causes of variations in kVp are line voltage drops and electrical component failure.

f. Interpretation of Results: Refer units deviating from the criteria in Table 2.1 for adjustment by a qualified service engineer. Proper kVp calibration is critical as it directly influences image quality and patient dose.

6. ***Beam Quality***

a. Purpose: To assure that the permanently installed filtration at the x-ray tube is maintained at an appropriate level to help minimize patient exposure.

b. Regulations: Federal and many state regulations specify minimum required HVLs at various kVp values. Reference (1), section 1020.30(m) Table 1 is reproduced and can be found at the end of this appendix as Table B-1. For 80 kVp the minimum HVL must be 2.3 mm of aluminum.

c. Equipment: Electrometer with small ion chamber, Five 1 mm Type 1100 Aluminum sheets, Two 0.5 mm Type 1100 Aluminum sheets (if available), BRH test stand (if available).

d. Procedure: Place the ion chamber 5 cm above the table top. Collimate the light field to a narrow beam geometry to include the ion chamber. The aluminum sheets should be placed between the ion chamber and the x-ray tube at a distance X/2, where X = focus to detector distance. Make sure the aluminum sheets intercept the entire beam (light field).
Make two exposures without any aluminum sheets in the beam. (An exposure made using 80 kVp, 0.10 sec and 320 mA to achieve an output of approximately 300 mR will ensure that you have a high enough exposure to make the measurements accurately and also ensures that your data can be plotted on semi-log paper where the scale is easy to read.) Add aluminum sheets and make additional exposures until the exposure is less than half of the original exposure. Recommend using 2, 3, and 4 mm aluminum. Remove all aluminum sheets and make one exposure. If exposure is not within 2% of the initial exposure, made with 0 mm of aluminum, repeat the measurement series ensuring that the technique and geometry selected remain the same throughout the procedure.

e. Possible Pitfalls:

(1) The entire ion chamber must be in the x-ray beam. When placing the sheets of aluminum in the beam, be sure that the entire beam is intercepted by the aluminum sheet. Once selected, the technique factors must not be altered for subsequent exposures.

(2) The kVp should be checked before measuring the HVL to ensure that it is within acceptable limits.

(3) The aluminum used for HVL measurements should be type 1100.

(4) For units produced before 1997, in which the HVL is greater than 3.5, further evaluation of the beam quality should be conducted. A service engineer should be consulted to evaluate the cause of the excessive HVL. Units made after 1997 may have dose reduction design characteristics that utilize higher than normal HVL.

f. Interpretation of Results: Plot the exposure values recorded on the semi-log graph paper. The exposure is on the y-axis and the added aluminum thickness is on the x-axis. See Figure B-1 at the end of this appendix for an example. Draw a straight line through the points on the graph. Draw a horizontal line from the point corresponding to one-half of the original exposure to the line drawn through the three exposure points on the graph. Draw a vertical line from that point to the lower horizontal scale and read the HVL (in mm of aluminum) off that scale. If the HVL is not greater than the minimum requirements listed above, consult a qualified service engineer. If the HVL is greater than 3.5 mm of Aluminum, further evaluation should be conducted to determine if the unit contains too much filtration.

7. ***Output Linearity Tracking by kVp***

a. Purpose: To ensure that the output of the x-ray unit is linear as the kVp is increased.

b. Regulations: The linear correlation coefficient should be greater than 0.990.

c. Equipment: Electrometer with small ion chamber.

d. Procedure: Utilize the setup described for reproducibility measurements. Measure and record the exposures obtained using the maximum mAs for each kV setting, incrementing by 10's from 50 kV to 150 kV, during acceptance testing. During periodic evaluation it may be necessary to evaluate a constant mAs at kVp settings from 60 kV to the maximum kV incrementing by 20 kV unless further measurements are necessary. Divide the mR output by mAs setting, record the mR/mAs as calculated..

e. Interpretation of Results: If the linear correlation coefficient is less than 0.990 consult a qualified service engineer. Output linearity between kVp stations is critical as it directly influences image quality and patient dose.

8. ***Light Field Intensity***

a. Purpose: To ensure that the light field intensity is adequate to illuminate the field.

b. Regulations: The light shall provide an average illumination of not less than 160 lux

(15 foot candles) at 100 cm or at the maximum source-image receptor distance (SID), whichever is less. (21CFRch1, 1020.31(d)(2)(ii))

c. Equipment: Light meter capable of providing either lux or foot candles.

d. Procedure: Place the light meter on the x-ray table top. Set the SID to 100 cm or the maximum available whichever is less. Collimate the x-ray beam to a 25 x 30 cm field. Illuminate the field. Measure and record the illumination in the 4 quadrants. Calculate an average.

e. Interpretation of Results: A qualified service engineer should be consulted if the average deviates from the criteria in Table 2.1.

9. ***Light Field/X-Ray Beam Alignment***

a. Purpose: To ensure that the x-ray field and the light field are congruent

b. Regulations: The light field/x-ray field alignment should be within ± 2% of the SID.(21CFRch1, 1020.31(d)(2)).

c. Equipment: Five coins or a x-ray beam alignment test tool (if available) and the collimator alignment template, film, and a ruler.

d. Procedure: Place a cardboard cassette or ready pack film on the x-ray table top. Center the light field on the film holder at a 40 inch SID. Tape the film holder to the table. Position the collimator alignment template so that it is centered in the light field and manually collimate the light field to the alignment marks on the template (or to 7x8 inch field size if the five coins are used). Place the x-ray beam alignment test tool in the exact center of the template. (If a test tool is not available place the edge of a coin on the each margin of the light field such that the edge of the coin is inside the light field. Place the fifth coin in the quadrant of the light field toward you and to the right as an orientation marker. Mark the center of the light field by laying a pen with the tip pointing at the light field center crosshair or use a radio-opaque B-B marker.) Make an exposure using 80 kVp, 32 mAs for ready pack film or 80 kVp and 20 mAs for a cardboard cassette. Place a loaded cassette in the bucky tray. Allow the PBL system to automatically collimate to the cassette size. (if available) Make a second exposure at 80 and < 1 mAs kVp,. Develop the films. From the film exposed on the table top, measure the deviation between the X-ray field and the edge of the light field (defined by the inscribed light field alignment marks on the test tool or the edges of the four coins).

e. Interpretation of Results: Consult a qualified service engineer if the alignment deviates from the criteria in Table 2.1.

9a. ***X-ray Field Size- Indicated vs. Actual***

a. Purpose: To ensure that the actual and indicated X-ray field are congruent.

b. Regulations: The indicated vs. actual x-ray field should be within ± 2% of the SID. (10 CFR 1020.31(e)(3))

c. Equipment: Bucky film developed from previous procedure and a ruler.

d. Procedure: Utilizing the bucky film developed in the previous procedure measure the size of the X-ray field.

e. Interpretation of Results: Consult a qualified service engineer if the alignment deviates from the criteria in Table 2.1.

10. ***Central Beam Alignment***

a. Purpose: To ensure that the central x-ray beam is perpendicular to the table.

b. Regulations: The perpendicularity of the central beam should be within 5mm.

c. Equipment: Table top film from procedure 9.

d. Procedure: If the x-ray beam alignment tool was used, measure the deviation between the upper (magnified) bead and the lower bead. If the five coins and marker were used, draw a line connecting the opposite corners of the x-ray field and measure the deviation between the location the lines cross and the marker.

e. Interpretation of Results: Consult a qualified service engineer if the perpendicularity measured deviates from the criteria in Table 2.1.

11. ***Indicated SID***

a. Purpose: To ensure the actual source to image distance (SID) and the indicated SID are congruent.

b. Regulations: The actual SID should be within ± 2% of the indicated SID.

c. Equipment: Tape measure.

d. Procedure: Position the tube assembly at 40 inches from the image receptor. Measure the SID. If a automatic detent is available, position the assembly utilizing the detent. Measure the SID.

e. Interpretation of Results: Consult a qualified service engineer if the measurement deviates from the criteria in Table 2.1.

12. ***Positive Beam Limiting System***

a. Purpose: To ensure that systems providing a beam limiting device function properly. Units manufactured after 3 May 1993 are not required to be equipped with a beam limiting device.

b. Regulations: Either the length or width of the x-ray field in the plane of the image receptor differs from the corresponding image receptor dimension by more than 3 % of the SID. (10 CFR 1020.31(g)(1)(i). The x-ray beam axis is perpendicular to the plane of the image receptor to within ± 3 degrees. (10 CFR 1020.31(g)(2)(iv).

c. Equipment: Table top and bucky films developed in procedure 9. Cassettes of various sized used clinically and scrap piece of film for each size cassette being tested.

d. Procedure:

(1) Place both the table top and the bucky tray film in the same orientation side by side on a viewbox. Determine the maximum are of the bucky tray film by observing the outermost image of the measuring scale (or coin edges) seen on the alignment template along all four dimensions of the film. Mark the corresponding numeric information onto the scale imaged on the table top film. Measure the difference between the area image on the bucky tray and table top films to determine the total misalignment. Measure the perpendicularity of the central beam as described in procedure 10.

(2) Set the x-ray tube at the SID commonly used. Make sure the PBL selector is set to automatic mode. Insert a cassette and ensure that the cassette is centered with the bucky tray centering light. Push the tray in and check visually that the changes in the light field size correspond with cassette size. Compare the light field with a scrap film of the same cassette size (in tray) by placing on the table top and measuring the differences using a ruler and record.

e. Interpretation of Results: The magnification factor should be factored in when calculating the size of the light field on the table top with respect to the size it should be in the bucky. Consult a qualified service engineer if the alignment deviates from the criteria in Table 2.1.

13a. ***Focal Spot Size***
(For focal spots less than 1.0 mm in size)

a. Purpose: To ensure that the focal spot size is within acceptable limits.

b. Regulations: National standards allow the measured size to be 1.5 x nominal perpendicular to the anode-cathode axis and 2.15 x nominal parallel to the anode-cathode axis. The nominal or stated size can usually be found in the technical manual or back of the tube head.

c. Equipment: 2 degree star pattern for focal spot sizes of 0.6 mm or greater, a 0.5 or small degree star pattern for smaller focal spot sizes, ready pack film. (A slit or pinhole camera may be used, the procedure will not be discussed in this section.)

d. Procedure: Choose the appropriate star pattern. Place the ready pack film or loaded cardboard cassette on the x-ray table top and tape it to the table top. Tape the star test pattern to the collimator face plate so that the radiographic central ray is perpendicular to the star pattern. (The star pattern may also be placed on a stand.) The central ray should pass through the center of the star pattern. The spokes of the pattern should lie along the tube axis. Place a radio-opaque marker on the table top to designate the anode/cathode axis. Set the focal spot-to-film distance (FFD) to twice the focal spot-to-test pattern distance (FTD) and collimate the beam so that the total test pattern is included in the field. (The FTD will be about 12" if you tape the test pattern to the collimator face plate.) You should have a magnification factor (M) of 2 (FFD/FTD). Expose the film using approximately 80 kVp and 32mAs for ready pack film or 80 kVp and 20 mAs for a cardboard cassette. Develop the film.

e. Interpretation of Results: Measure the total diameter of the star pattern image on the radiograph. This dimension should be about 90 mm ± 2 mm, assuming a 45 mm star target. Divide the diameter measured on the radiograph by the true diameter. The magnification factor, M = FFD/FTD, should be about 2. Starting at the outside edges of the star test pattern and the same direction as the anode-cathode axis, move toward the center of the image and mark on both sides where the bars first disappear. Repeat the procedure in the other direction, i.e., 90 degrees to the anode-cathode axis. With small focal spots, you should count the number of imaged spokes to ensure first blur is visible. With a clear plastic ruler measure the distance between the marks and record these dimensions with respect to the anode-cathode axis. Repeat for 90 degree axis. Compute the focal spot size using the following equation:

$$F = \frac{N x D}{57.3(M-1)}$$

F: focal spot size in mm
N: degrees in star pattern
D: diameter of zero contrast region in mm
M: magnification

The width is determined by the measured dimension along the anode-cathode axis and the length is computed from the dimension measured at 90 degrees to the anode-cathode axis.

Focal spot size can indicate the physical condition of the anode. If the anode is pitted due to age or abuse the focal spot size will increase compared to the values obtained from previous x-ray surveys. Thus, the results can help determine if the unit or insert is due for replacement.

13b. ***Focal Spot Constancy***
(alternative method for periodic evaluation)

a. Purpose: To ensure that the spatial resolution of the x-ray system is remaining constant.

b. Regulations: During periodic evaluations the spatial resolution should not change significantly over time.

c. Equipment: Right cylinder power target test tool, ready pack film /cardboard cassette.

d. Procedure: Utilize the setup described for the focal spot size measurement. The magnification factor should be greater than 2. Two exposures are required, one with the bar pattern oriented parallel to the anode-cathode axis and one with it oriented perpendicular.

e. Interpretation of Results: The high-contrast resolution pattern images should be viewed under masked conditions with a 10x to 30x magnification. If the resolution has significantly changed since the last further evaluation of the focal spot size should be conducted to determine if the unit or insert is due for replacement.

14. ***Automatic Exposure Control (AEC) System*** (if applicable)

a. Purpose: To ensure that the automatic exposure control system is responding adequately. The system compensates for variations in technique factors and patient thickness such that resulting films appear with constant, optimal densities. This evaluation assumes proper operation of the processor used to develop films. It also assumes that the AEC system is calibrated for the film/screen combination used with the unit. Therefore, the processor, cassette, and film used for testing should be those actually used during patient imaging. Also, test films should all come from the same emulsion batch. The following AEC parameters should be evaluated during testing: reproducibility, balance, maximum exposure time, kVp compensation, thickness compensation and density control tracking.

b. Regulations: For each ion chamber measurement the reproducibility should be within ± 5%. In comparing each ion chamber, all measurements should be within ± 0.1 OD of each other. Back up timer should terminate the exposure at 600 mAs or 2000 mAs for tube potentials less than 50 kVp. Film optical densities should be less than ± 0.3 for thickness compensation and kVp compensation. Density control function should vary approximately 25% between settings.

c. Equipment: 4 cm Al or 18 cm acrylic phantom, 1.6 mm Pb plate, 14” x 17” (35 cm x 43 cm) loaded cassette, electrometer with small ion chamber.

d. Procedure: For a radiographic system, set the x-ray tube at 40 inches (72 inches for chest systems) target film distance and center to the cassette. Set selector such that only one phototimer is activated. To determine the location of the phototimer(s) look at the chest unit pattern of rectangles on the chest board surface. Use the same layout for the table, noting that the center chamber is usually located at the lateral center of the table when the tube and bucky are aligned. Record the SID, film/screen combination and film size used for future testing reproducibility. Place a loaded cassette in the bucky tray. Place a 4 cm aluminum or 15 cm acrylic phantom in the beam. Ensure that the phantom covers all the AEC detector cells. Best results occur if the attenuator is placed on the table or at the chest board surface. If doubt exist for the location of the chamber, place the attenuator at the collimator. Set the control in the photo-timing mode, 80 kVp and select the detector to be checked (e.g. table, center chamber). A single cassette should be used for all testing, to reduce variability. This will require processing the film after each exposure.

(1) Optical Density (OD): Make an exposure using the setup described. Develop the film. Measure and record the OD at the center of the field. The OD should be at least 1.2. The radiologist may set a higher baseline density. The range of densities should be within ± 0.15 of the baseline density. If the OD does not fall within this range further evaluation is required to determine if the x-ray system requires adjustment or if the processor is not functioning properly.

(2) Output Reproducibility: Use the setup previously described. Place the ion chamber along the beam central axis at the phantom beam entrance surface. Set the technique at 80 kVp, 200 mA, AEC setting to neutral (0). Substitute an exposed piece of film for fresh film during this test. Irradiate the phantom, ion chamber and cassette holding exposed film three times. Record the exposure readings and calculate their mean. All three readings should line within ± 5% of their mean. Repeat for each detector.

(3) Back-up Timer: Use the setup previously described. Place the lead sheet over the AEC detector fields so that no radiation reached them. Set the technique at 80 kVp, 200 mA, AEC setting to neutral (0). Retain the previously exposed film from the reproducibility test. Irradiate the phantom until the AEC shuts off the beam. Record the elapsed mAs. The beam should terminate prior to the accumulation of 600 mAs or 2000 mAs for tube potentials less than 50 kVp.

(4) Phototimer Balance: Use the setup previously described. Place a fresh piece of film in a cassette and load the bucky tray. Set the technique at 80 kVp, 200 mA, AEC setting to neutral (0). Irradiate a separate piece of film for each detector. Record the elapsed mAs for each image and measure OD at the center of each processed film using a densitometer. The densities should lie within the range of ± 0.1 of the baseline density.

(5) Patient Thickness Compensation: Use the setup described previously. Place a fresh piece of film in a cassette and load the bucky tray. Set the technique at 80 kVp, 200 mA, AEC setting to neutral (0). Vary the phantom thickness over the range: 2, 4 cm Al or 12, 15, 18 cm acrylic, irradiating a separate film for each phantom thickness. Record the elapsed mAs for each image and measure OD at the center of each processed film using a densitometer. The densities should lie within the range of ± 0.3 of the baseline density.

(6) kVp Compensation: Use the setup previously described. Place a fresh piece of film in a cassette and load the bucky tray. Set the technique at 80 kVp, 200 mA, AEC setting to neutral (0). Vary the kVp over the clinically used range 70, 90, 110, irradiating a separate film for each voltage applied. Record the elapsed mAs for each image and measure OD at the center of each processed film using a densitometer. The densities should lie within the range of ± 0.3 of the baseline density.

(7) Density Control Tracking: Use the setup previously described. Place the ion chamber just off the beam central axis at the phantom beam entrance surface. Set the technique at 80 kVp and 200 mA. Vary AEC density over the range of available positive and negative settings, exposing a new piece of film for each setting. Record the elapsed mAs, density at the center of each film, and exposure for each image. The density function should operate as expected, + gives exposure and density increase, - gives exposure and density decrease. The exposure difference per step should meet the manufacturer’s specifications or in the absence of such data, be balanced about the neutral setting output at 25% per step.

e. <u>Interpretation of Results:</u> Units deviating from the criteria in Table 2.1 should be referred for adjustment by a qualified service engineer.

15. ***Entrance Skin Exposure Measurements (ESE)***

See chapter 15 and appendix I.

B. Survey Procedures for Portable and Mobile Radiographic Equipment

The following modifications of quality control procedures and acceptance parameters from fixed x-ray units apply for portable and mobile units:

1. ***Visual Inspection***

a. The minimum source to skin distance must be no less than 12 inches (30 cm). This can be measured directly with a tape measure provided the location of the focal spot is known.

b. The operator must be able to stand at least six feet away from the x-ray tube during the actual exposure. This is normally accomplished by attaching the exposure switch to the unit with at least a six foot long cord.

c. Each portable unit should be supplied with at least two lead aprons and gonadal shields for use with children and patients under the age of 45.

2. ***Generator checks***

a. Conventional portable generators

Pay special attention to short exposure times such as those used in chest radiography. On single mA station equipment, perform reproducibility studies at a short (1/60 - 1/30 sec), medium (1/2 sec) and long (> 1 sec) exposure time. Although not a true linearity, compare the mR/mAs for 3 or 4 time stations.

b. Battery powered generators

Perform a battery depletion study. Completely charge the storage batteries. Select an average technique for the day-to-day work load. Using a dosimeter, measure the output for three exposures at the preselected technique. If the machine has power assisted motion, drive the unit the typical distance one would travel between patient rooms. Repeat the three exposures and movement sequence until the output falls to 80% of its initial level. Plot output versus the number of exposures. If the typical number of exposures per portable run falls short of the number required to reduce output to the 80% level, operators should have little trouble producing consistent density images if all other radiographic factors are properly controlled.

c. Capacitor discharge generators

The kVp measurement on capacitor discharge equipment will need special acceptance limits. A typical capacitor discharge unit (1 microfarad capacitor) will lose 1 kVp for each mAs of exposure. For example, a typical kVp test cassette exposure for 80 kVp will require 20 mAs, and will yield a final minimum of 60 kVp with an average kVp of about 70. Also, the filtration used in the test cassette preferentially attenuates lower energy photons, which will yield a kVp reading higher than the average kVp.

3. ***Performance Limits***

a. Conventional and battery-powered portable units should meet the performance limits outlined for fixed equipment. Capacitor discharge equipment should meet all fixed system performance limits except for measured kVp. The kVp should be measured with a non-invasive device after the system has been calibrated by a service engineer. The quality control test result (at a specific mAs), rather than the indicated kVp, becomes the operating level.

b. All of the appropriate output quantities should be evaluated any time major maintenance is performed, especially battery service.

<u>**Table B-1**</u>

Minimum Half Value Layer Requirements (HVL)

(From Code of Federal Regulations, 10 CFR, Part 1020.30)

X-ray tube voltage (kilovolt peak -kVp)		Minimum HVL (millimeters of Al)	
Designed operating range	Measured operating potential	Specified dental systems	Other X-ray systems
Below 51...	30	1.5	0.3
	40	1.5	0.4
	50	1.5	0.5
51 to 70	51	1.5	1.2
	60	1.5	1.3
	70	1.5	1.2
Above 70...	71	2.1	2.1
	80	2.3	2.3
	90	2.5	2.5
	100	2.7	2.7
	110	3.0	3.0
	120	3.2	3.2
	130	3.5	3.5
	140	3.8	3.8
	150	4.1	4.1

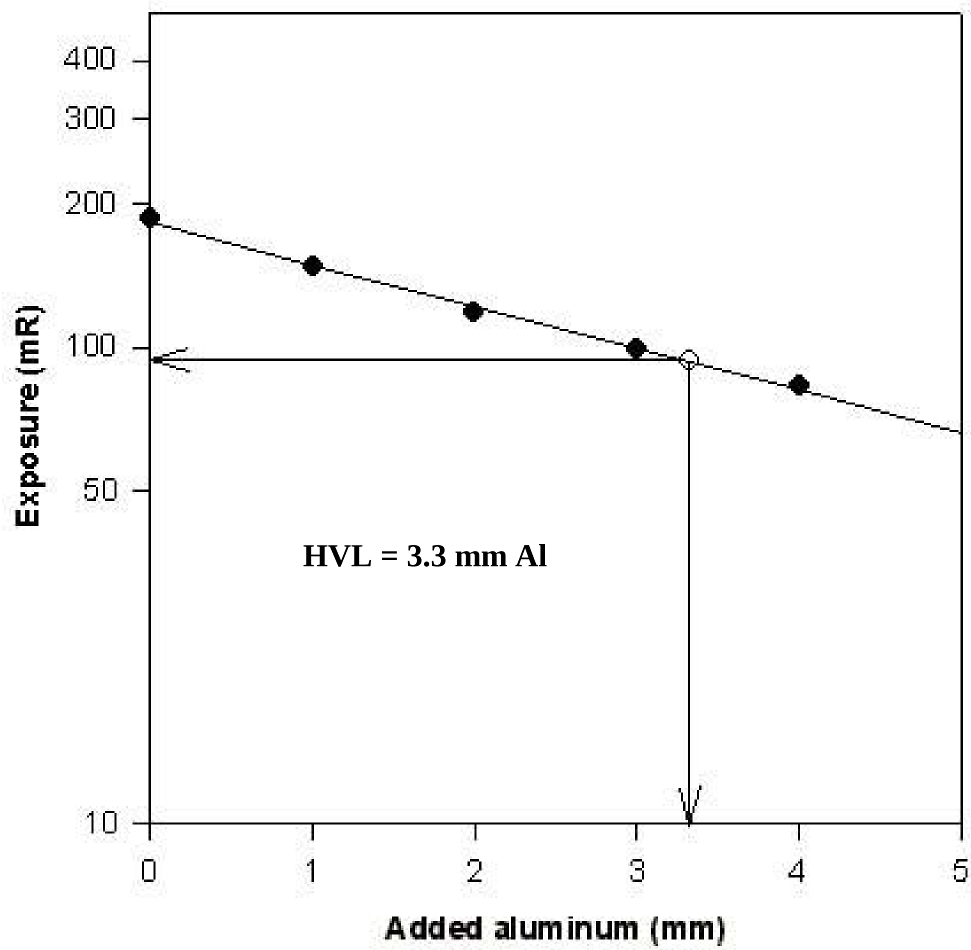

Figure B-1: Determination of X-Ray Beam Quality (Half Value Layer - HVL)

GENERAL RADIOGRAPHIC EQUIPMENT DATA FORMS

MEDICAL/DENTAL X-RAY EQUIPMENT DATA
NAVMED 6470/4 (7-80) REPORT SYMBOL MED 6470-15

1. FACILITY IDENTIFICATION

a. FACILITY NAME	b. UIC	
c. MAILING ADDRESS	d. BUILDING	e. ROOM

2. STATUS OF THE EQUIPMENT (INDICATE IF EQUIPMENT IS IN USE OR THE REASON FOR NOT BEING IN USE).

☐ IN USE ☐ TO BE REPAIRED ☐ STORED IN GOOD WORKING CONDITION
☐ NOT IN USE ☐ CANNOT BE REPAIRED ☐ OTHER

3. X-RAY EQUIPMENT IDENTIFICATION

a. PLANT ACCOUNT NUMBER
b. YEAR EQUIPMENT WAS MANUFACTURED
c. INSTALLATION DATE OF EQUIPMENT
d. X-RAY EQUIPMENT IS CERTIFIED: YES ____ NO ____

e. COMPONENT	f. MANUFACTURER	g. MODEL	h. SERIAL NUMBER
1) CONTROL CONSOLE			
2) X-RAY TABLE			
3) X-RAY TUBE ASSEMBLY			
TUBE #1 HOUSING			
TUBE #1 INSERT			
TUBE #1 COLLIMATOR			
IMAGE INTENSIFIER			

☐ CONTINUED ON SEPARTE SHEET

4. TYPE OF X-RAY EQUIPMENT (CHECK AS MANY AS APPROPRIATE)

☐ RADIOGRAPHIC ☐ FIXED ☐ DENTAL INTRAORAL
☐ FLUOROSCOPIC ☐ MOBILE ☐ DENTAL PANOGRAPHIC
☐ COMBINATION R/F ☐ OTHER ________________________

5. GENERATOR (CHECK ONE)

☐ AUTORECTIFIED ☐ THREE PHASE MAXIMUM mA ____ mA
☐ SINGLE PHASE HALF WAVE ☐ CAPACITOR DISCHARGE
☐ SINGLE PHASE FULL WAVE ☐ OTHER (SPECIFY) ________________ MAXIMUM kVp ___ kVp

6. ASSOCIATED EQUIPMENT (CHECK AS MANY AS APPROPRIATE)

☐ AUTOMATIC EXPOSURE CONTROL SYSTEM (LIKE PHOTOTIMER) ☐ PHOTOSPOT CAMERA
☐ SPOT FILM DEVICE ☐ OTHER _______________ ☐ IMAGE INTENSIFIER

7. USE (CHECK ONE)

☐ GENERAL RADIOGRAPHY ☐ MAMMOGRAPHY ☐ OTHER (SPECIFY) ____________________________
☐ CHEST RADIOGRAPHY ☐ TOMOGRAPHY
☐ HEAD RADIOGRAPHY ☐ UROLOGY STUDIES

8. DATE OF LAST RADIATION PROTECTION SURVEY DATE: ☐ UNKNOWN	9.THIS EQUIPMENT REPLACED EQUIPMENT WITH PLANT ACCOUNT NUMBER. ☐ UNKNOWN

10. REPORTED BY: TITLE:	REVIEWED BY:	DATE:

GENERAL REQUIREMENTS FOR RADIOGRAPHIC EQUIPMENT
NAVMED 6470/5 (12-89) REPORT SYMBOL MED 6470-10

1. FACILITY IDENTIFICATION

a. FACILITY NAME	b. UIC	
c. MAILING ADDRESS	d. BUILDING	e. ROOM

2. RADIATION SAFETY EQUIPMENT AND ACCESSORIES

EQUIPMENT OR ACCESSORY	YES	NO	COMMENTS
a. APRONS: ADEQUATE NUMBER			
GOOD CONDITION			
b. GLOVES: ADEQUATE NUMBER			
GOOD CONDITION			
c. GONADAL SHIELDS TYPE: Leaded Rubber Shield			
d. ADEQUATE PATIENT IMMOBILIZATION EQUIPMENT			
e. WARNING LABLELS PRESENT AT CONTROL PANEL (CERTIFIED EQUIPMENT REQUIREMENT)			
f. LIGHTS, METERS IN GOOD WORKING CONDITION.			
g. INTERLOCKS ARE SATISFACTORY.			
h. MECHANICAL/ELECTRICAL STOPS IN GOOD CONDITION			
i. CABLES AND GROUPING IN GOOD CONDITION.			

3. GENERAL CHARACTERISTICS AND PERFORMANCE REQUIREMENTS.

EQUIPMENT OR ACCESSORY	YES	NO	COMMENTS
a. MEANS TO CENTER X-RAY SOURCE OVER IMAGE RECEPTOR IS AVAILALBE (FIXED EQUIPMENT)			
b. TECHNIQUE FACTORS INDICATED BEFORE EXPOSRE.			
c. TECHNIQUE FACTORS VISIBLE AT OPERATORS POSITION.			
d. EXPOSURE TERMINATED AFTER: PRESET: TIME ☐ mAs ☐ NO. OF PULSES ☐ OR RADIAION EXPOSURE TO IMAGE RECEPTOR. ☐			
e. EXPOSURE SWITCH AT ADEQUATE LOCATION.			
f. EXPOSURE SWITCH REQUIRES CONTINUOUS PRESSURE TO OPERATE.			
g. EXPOSURE NOT POSSIBLE WITH THE TIMER IN AN OFF OR ZERO POSITION.			
h. VARIABLE COLLIMATION DEVICES ARE PROVIDED WITH LIGHT FIELDS.			

GENERAL REQUIREMENTS FOR RADIOGRAPHIC EQUIPMENT (CON'T)

NAVMED 6470/5 (12-89) REPORT SYMBOL MED 6470-10

3. GENERAL CHARACTERISTICS AND PERFORMANCE REQUIREMENTS. (CONT)

EQUIPMENT OR ACCESSORY	YES	NO	COMMENTS
i. AUDIBLE INDICATION OF EXPOSURE TERMINATION.			
j. VISIBLE "BEAM ON" INDICATION.			
k. MEANS TO INDICATE WHEN BEAM AXIS IS PERPENDICULAR TO THE IMAGE RECEPTOR.			
l. MEANS OF STEPLESS ADJUSTMENT OF X-RAY FIELD SIZE.			
m. BEAM LIMITING DEVICE NUMERICALLY INDICATES FIELD SIZE.			
n. POSITIVE BEAM LIMITING DEVICE (PBL) IN OPERATING CONDITION.			
o. PBL MODE: ADJUSTMENT POSSIBLE TO FIELDS SMALLER THAN IMAGE RECEPTOR. *			
p. AUTOMATIC RETURN TO PBL WHEN IMAGE RECEPTOR IS CHANGED. *			
q. X-RAY PRODUCTION PREVENTED AT SID'S WHERE OPERATION IS NOT INTENDED.			

*GENERAL PURPOSE X-RAY EQUIPMENT

4. MOBILE X-RAY EQUIPMENT

EXPOSURE SWITCH IS LOCATED SO THAT OPERATOR CAN STAND AT LEAST 6 FEET FROM PATIENT AND USEFUL BEAM.

YES _____ NO _____

5. CHARTS AVAILABLE AND POSTED.

TECHNIQUE CHARTS YES ______ NO _____

RATING CHARTS YES ______ NO _____

6. REMARKS

SURVEYOR:	DATE:

GENERAL REQUIREMENTS FOR RADIOGRAPHIC/DENTAL EQUIPMENT

NAVMED 6470/6 (5-01) REPORT SYMBOL MED 6470-10

I. FACILITY IDENTIFICATION

a. FACILITY NAME	b. UIC	
c. MAILING ADDRESS	d. BUILDING	e. ROOM

II. X-RAY EQUIPMENT IDENTIFICATION

1. X-RAY TUBE HOUSING:

a. MODEL: b. SERIAL NO. c. CERTIFIED: YES _____ NO _____

III. RADIATION EXPOSURE MEASUREMENTS

1. RADIATION EXPOSURE AND TIMER REPRODUCIBILITY.

a. kVp	b. mA	c. Time	d. Distance SID: TDD:

e. MEASUREMENTS

	Exposure	Timer		Exposure	Timer
1	mRad	msec	6	mRad	msec
2	mRad	msec	7	mRad	msec
3	mRad	msec	8	mRad	msec
4	mRad	msec	9	mRad	msec
5	mRad	msec	10	mRad	msec

	Exposure	Timer
mean		
SD		
CV		

2. TIMER ACCURACY

a. kVp	b. mA	c. Distance SID: TDD:

d. MEASUREMENTS

	TIME SETTING	TIME MEASURED	-10%	+10%
1	mSec	mSec		
2	mSec	mSec		
3	mSec	mSec		
4	mSec	mSec		
5	mSec	mSec		

	TIME SETTING	TIME MEASURED	-10%	+10%
6	mSec	mSec		
7	mSec	mSec		
8	mSec	mSec		
9	mSec	mSec		
10	mSec	mSec		

3. LINEARITY OF X-RAY OUTPUT

a. kVp	b. Time	SID	TDD

LINEARITY OF mR/mAS

mA	mRad	mR/mAs	X1-X2	0.1(X1+X2)

OUTPUT LINEARITY TRACKING BY kVP

kVp	mA	Time	mRad	mR/mAs

R value

4. INSTRUMENT USED:

a. TYPE	b. MODEL	c. SERIAL NUMBER	d. CALIBRATION DATE

REMARKS

GENERAL REQUIREMENTS FOR RADIOGRAPHIC/DENTAL EQUIPMENT (CON'T)

NAVMED 6470/6 (5-01) REPORT SYMBOL MED 6470-10

5. KILOVOTAGE ACCURACY

	a. kVp SETTING	b. kVp DETERMINED	c. ACCURACY
1)	kVp	kVp	
2)	kVp	kVp	
3)	kVp	kVp	
4)	kVp	kVp	
5)		kVp	

d. kV CHECKING DEVICE USED:

1) TYPE:

2) MODEL:

3) SERIAL NUMBER:

6. BEAM QUALITY

a. kVp	b. mA	c. Time	d. Distance	OTHER

f. MEASUREMENTS

g. HVL

mmAl

EQUIVALENT

ADDED FILTRATION	EXPOSURE
mmAl	mR
mmAl	mR
mmAl	mR
mmAl	mR
mmAl	mR
mmAl	mR

h. EQUIPMENT COMPLIES WITH HVL REQUIREMENTS:

YES _____ NO _____

COMMENTS: ________________

____

Exposure reading that is just less than one-half of initial reading. mR Corresponding Al thickness. mm

Exposure reading that is just greater than one-half of initial reading. mR Corresponding Al thickness. mm

CERTIFIED EQUIPMENT: HVL SHALL NOT BE LESS THAN VALUES LISTED IN TABLE 1 SECTION 1020.30 OF TITLE 21, CHAPTER 1 CFR PART 1020.

OTHER EQUIPMENT: HVL SHOULD BE AS RECOMMENDED IN SECTION 3.2.1. OF NCRP REPORT 33.

REMARKS

REQUIREMENTS FOR RADIOGRAPHIC EQUIPMENT

NAVMED 6470/6 (10-99) REPORT SYMBOL MED 6470-10

IV. OTHER MEASUREMENTS

1. LIGHT FIELD INTENSITY

	QUADRANT 1	QUADRANT 2	QUADRANT 3	QUADRANT 4	AVERAGE
lux / footcandles					lux / ftcd

2. LIGHT FIELD/X-RAY BEAM ALIGNMENT

1) LENGTH MISALIGNMENT	mm
2) WIDTH MISALIGNMENT	mm
3) CENTERS MISALIGNMENT	mm
4) INDICATED SID	cm
5) MEASURED SID	cm

X-RAY FIELD IS ALIGNED WITH LIGHT FIELD (MISALIGNMENT DOES NOT EXCEED 2% OF SID IN CERTIFIED EQUIPMENT).

YES ☐ NO ☐

3. X-RAY FIELD SIZE - INDICATED VS. ACTUAL

1) LENGTH MISALIGNMENT	mm
2) WIDTH MISALIGNMENT	mm
3) INDICATED SID	cm

ACTUAL X-RAY FIELD IS ALIGNED WITH INDICATED X-RAY FIELD (MISALIGNMENT DOES NOT EXCEED 2% OF SID IN CERTIFIED EQUIPMENT).

YES ☐ NO ☐

4. FOCAL SPOT LOCATION AND INDICATED SID

a. MINIMUM FOCAL SPOT TO SKIN DISTANCE DETERMINED BY (CHECK ONE).

TRIANGULATION ☐ TAPE MEASURE ☐ Is: --- INCHES

THIS DISTANCE SHALL BE AT LEAST 30 cm (12 INCHES) FOR MOBILE EQUIPMENT).

b. INDICATED SID IS CORRECT WITHIN 2% OF TRUE SID:

YES ☐ NO ☐

5. POSITIVE BEAM LIMITING SYSTEM

SID

a. INDICATED X-RAY FIELD	b. MEASURED X-RAY FIELD TABLE-TOP	BUCKY TRAY	ACCURACY	c. PERPENDICULARITY OF CENTRAL BEAM MISALIGNMENT	ACCURACY

REMARKS

Revised 5/2/01

REQUIREMENTS FOR RADIOGRAPHIC EQUIPMENT (CON'T)

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6. FOCAL SPOT

a. FOCAL SPOT SIZE	b. kVp	c. mA	d. TIME	e. SID	f. Source Obj. Distance	g. Estimated Focal Spot Size
1) SMALL ___ mm						
2) LARGE ___ mm						

h. TEST OBJECT USED: ______ g. SERIAL No. ______

a. FOCAL SPOT CONSTANCY	b. kVp	c. mA	d. TIME	e. SID	f. Source Obj. Distance	g. Line Pairs Resolved
1) SMALL ___ mm						
2) LARGE ___ mm						

h. TEST OBJECT USED: ______ g. SERIAL No. ______

7. AUTOMATIC EXPOSURE CONTROL (AEC) SYSTEM

SID:	FLIM/SCREEN COMBINATION:	FILM SIZE:	

a. OPTICAL DENSITY EVALUATION (Baseline Optical Density):

kVp	mA	Detector Cell	AEC Setting	Phantom Thickness	Image Number	Elapsed mAs	Measured OD

b. OUTPUT REPRODUCIBILITY

Detector Cell		Reading 1	Reading 2	Reading 3	Mean
	Output (mR)				
	Output (mR)				
	Output (mR)				
	Output (mR)				

c. BACK-UP TIMER

kVp	mA	AEC Setting	Lead Thickness	SID	

Detector Cell	Elapsed mAs

DOES THE BEAM TERMINATE PRIOR TO 600 mAs OR 2000 mAs FOR TUBE POTENTIALS LESS THAN 50 kVp.

YES ______ NO ______

d. PHOTOTIMER BALANCE

kVp	mA	AEC Setting	Type and thickness of Phantom	SID

Detector Cell	Elapsed mAs	Measured OD	Density difference from Baseline

Do all densities lie within +/- 0.1 of baseline density determined in 7a. yes / no

REMARKS

REQUIREMENTS FOR RADIOGRAPHIC EQUIPMENT (CON'T)

NAVMED 6470/6 (5-01) REPORT SYMBOL MED 6470-10

7. AUTOMATIC EXPOSURE CONTROL (AEC) SYSTEM (CONTINUED)

e. PATIENT THICKNESS COMPENSATION

kVp	mA	Imaging Mode	

Phantom Thickness	Recorded mAs	Optical Density

Density Range

Do all densities lie within +/- 0.3 of baseline density determined in 7a. Yes / No

f. kVp COMPENSATION

mA 200	Phantom Thickness 4 cm Al	AEC Setting neutral center cell

kVp	Recorded mAs	Optical Density

Density Range

Do all densities lie within +/- 0.3 of baseline density determined in 7a. Yes / No

g. DENSITY TRACKING

kVp	mA	Phantom Thicknes	SID

			Relative to Normal		
Density Setting	Recorded mAs(I)	Measured OD (OD(i))	mAs(I)/mAs(n)	OD(i)-OD(n)	% difference from neutral setting OD

8. CONCLUSIONS

	YES	NO
a. EXPOSURE REPRODUCIBLE FOR SAME EXPOSURE FACTORS WITHIN 5%		
b. RADIATION EXPOSURE VARIES LINEARLY WITH EXPOSURE TIME OR PULSES.		
c. THE ACCURACY OF THE TIMER IS WITHIN 10% OF THE SELECTED TIMER SETTING OR ± 1mS FOR EXPOSURE TIMES SMALLER THAN 10 mSECONDS.		
d. RADIATION EXPOSURE VARIES LINEARLY WITH TUBE CURRENT (mA) AND mAs.		
e. kVp DETERMINED IS WITHIN ± 5 KvP OF INDICATED AT THE CONTROL PANEL.		
f. HALF VALUE LAYER COMPLIES WITH 21 CFR 1020.30		
g. LIGHT FIELD INTENSITY MEASUREMENTS INDICATE AVERAGE ILLUMINANCE GREATER THAN 160 LUX (15 ftcd) AT 100 CM OR AT THE MAX SID WICHEVER IS LESS		
h. TOTAL MISALIGHNMENT OF EDGES OF LIGHT FIELD VS. X-RAY FIELD DID NOT EXCEED 2% OF THE SID ALONG EITHER LENGTH OR WIDTH.		

REQUIREMENTS FOR RADIOGRAPHIC EQUIPMENT (CON'T)

NAVMED 6470/6 (10-99) REPORT SYMBOL MED 6470-10

8. CONCLUSIONS (CONTINUED)

	YES	NO
I. INDICATED X-RAY FIELD SIZE IS WITHIN 2% OF ACTUAL SIZE AT SID.		
j. CENTRAL BEAM ALIGNMENT WITHIN 5 mm.		
k. INDICATED SID WITHIN 2% OF MEASURED SID.		
l. MEASURED X-RAY FIELD DOES NOT DIFFER BY MORE THAN 3% OF CORRESPONDING IMAGE RECEPTOR DIMENSIONS.		
m. FOCAL SPOT CONSTANCY DOES NOT DIFFER SIGNIFICANTLY FROM LAST SURVEY.		
n. OPTICAL DENSITY EVALUATION INDICATES A MEASURED OPTICAL DENSITY OF 1.2 +/- 0.15 AT THE CENTER OF THE FIELD.		
o. AEC OUTPUT REPRODUCIBILITY RESULTS WERE ALL LESS THAN +/- 5% OF MEAN OF THREE EXPOSURES PER SELECTED CELL.		
p. kVp COMPENSATION IN THE AEC MODE FOR SELECTED kVp's PRODUCED OPTICAL DENSITIES OF 1.2 +/- 0.3 .		
q. OPTICAL DENSITIES OBTAINED DURING EVALUATION OF DETECTOR CELL TRACKING INDICATED ABOUT 25% BETWEEN SETTINGS.		
r. EVALUATION OF DETECTOR CELL BALANCE (CENTER TO EACH SIDE) PRODUCED OPTICAL DENSITIES OF 1.2 +/- 0.1 FOR EVALUATED FILMS.		
s. EVALUATION OF BACK UP TIMER INDICATED AN ELAPSED mAs OF LESS THAN 600 mAs FOR TUBE POTENTIALS GREATER THAN 50 kV.		
t. ENTRANCE SKIN EXPOSURE MEASUREMENTS WERE WITHIN +/- 20 % OF THE MOST CURRENT NEXT REPORT.		

REMARKS

SURVEYOR:	DATE:

Appendix C

Performance Tests for Dental Units

Intraoral and Panoramic

A. Requirements For Dental Intraoral Units

1. ***Exposure and Timer Reproducibility***

a. Purpose: To ensure that exposure received for the same mA, time, and kVp is the same from exposure to exposure.

b. Regulations: Determination of reproducibility is based on five consecutive measurements within a time period of thirty minutes, using the same technique factors. The exposures must have a coefficient of variation (CV) less than 5%. Reference: 21 CFR 1020.31(b)(1).

c. Equipment: Ion chamber.

d. Procedure:

(1) Place the probe 10 inches from the focal spot as marked on the tube head.

(2) Visually center the probe in the beam, checking from the front and the sides to ensure that the beam will strike the probe. Once established, this set up should not be varied during this test.

(3) Select the most commonly used patient technique and make five exposures, rotating all dial settings between exposures. Always wait at least 30 seconds between exposures so as not to overheat the tube.

(4) Record the pulse exposure in mR (milli-Roentgen) and the pulse duration in msec (milliseconds).

e. Interpretation of results: The exposures must have a coefficient of variation (CV) less than 5%. See section 1 of Appendix B for calculation of CV. If all values are within a few mR of each other, this calculation is not necessary.

2. ***Timer Accuracy***

a. Purpose: To ensure that the x-ray generator is producing the exposure time as set on the control panel.

b. Regulations: The accuracy of the timer should be within 10% of the selected setting.

c. Equipment: Same as above.

d. Procedure: Keep the same set-up as for reproducibility, holding kVp and mA constant. Select three commonly used patient timer settings by consulting either the technician or the technique chart. Make an exposure at each setting, recording mR and msec.

e. Interpretation of results: Pulse duration measured should be within 10% of the nominal setting or as specified by the manufacturer. Also, pulse exposure should increase linearly with time, i.e., exposure should increase by approximately the same percentage as the time is increased.

3. ***Linearity of mR/mAs***
(Please note that this test cannot be done on fixed kVp or mA units.)

a. Purpose: To ensure that similar exposures are obtained for the mAs and kVp regardless of the exposure time and mA.

b. Regulations: The average ratios of exposure to indicated mAs (mR/mAs) obtained at two tube current settings should not differ by more than 0.10 times their sum.

c. Equipment: Same as above.

d. Procedure:

(1) With the equipment in the same set-up as above, record one of the reproducibility results as the first reading.

(2) Switch to another mA station if one exists while holding kVp and timer settings constant.

(3) Make an exposure and record pulse exposure, then divide mR output by mAs setting.

(4) Record this mR/mAs as calculated.

e. Interpretation of results: These two mR/mAs results should be similar, specifically the difference between the two divided by sum of the two should not exceed 10%. Repeat this test at several kVp settings.

4. ***KVp Accuracy and Precision***

a. Purpose: To ensure that the x-ray generator is producing the kVp as indicated on the control panel.

b. Regulations: The accuracy must be within 5 kVp of the control panel setting (Some units have fixed kVp and must be within 5 kVp of that value).

c. Equipment: kVp meter.

d. Procedure:

(1) Select the proper phase switch on the kVp meter (most dental units are single phase).

(2) Center the end of the cone on the kVp meter so that the x-ray field will cover the required area of the kVp meter.

(3) Check 90 kVp at one-half second, 80 kVp at one second and 70 kVp at two seconds. Four measurements should be obtained at the most clinically used setting.

(4) For fixed kVp units, determine the actual kVp.

(5) Allow for tube cooling between longer shots, e.g., one minute for one second, two minutes for two seconds, etc.

e. Interpretation of results: The meter reading should be within five kVp of each setting. The coefficient of variation should be less than 0.02.

5. ***Beam Quality (Half-Value Layer (HVL) Determination)***

a. Purpose: To assure that the permanently installed filtration at the x-ray tube is maintained at an appropriate level to help minimize patient exposure.

b. Regulations: The minimum value of the HVL shall be as stated in Table B-1 for the actual kVp determined above.

c. Equipment: Electrometer with small ion chamber, sheets of type 1100 alloy aluminum

d. Procedure:

(1) Set the control console for 80 kVp, if the unit does not have fixed kVp.

(2) Take an exposure using the set-up for the reproducibility test.

(3) Measure the radiation and record the value as the exposure with zero mm Al added.

(4) Next, tape one mm Al (use tape which does not leave marks, such as paper surgical tape, or whatever is conveniently available) on the end of the cone and take a reading at the same settings, recording this for one mm Al added.

(5) Repeat for two, three and four mm of Al.

(6) Finally, remove all Al and take one last reading with zero mm Al. As a rule of thumb, the four mm trial is not needed if three mm cuts the initial reading in half. If the final exposure is not within 2% of the initial exposure made with 0 mm of Al, repeat the measurement series ensuring that the technique and geometry selected remain the same throughout the procedure.

e. Interpretation of results:

(1) Use the average of the two zero readings as the unattenuated value.

(2) The HVL may be determined mathematically using logarithmic interpolation or graphically using semi-log paper. Refer to the general radiographic beam quality section for a description.

(3) The HVL must meet FDA standards for the actual kVp used which was determined above.

FDA standards for half-value layers, for dental units, are included in Table B.1.

6. ***Source To Skin Distance And X-Ray Field Size/Cone Alignment***

a. Purpose: To determine the minimum source to patient distance and field size.

b. Regulation: The source to skin distance and field size shall be as stated in 21 CFR 1020.31(f)&(h).

c. Equipment: Measuring tape and fluorescent screen.

d. Procedure:

(1) Measure and record the length of the removable cone, the distance between the focal spot and end of the cone and the inner diameter of the cone.

(2) Use the fluorescent screen to ensure the x-ray beam at the end of the cone is the same size as the cone.

7. ***Entrance Skin Exposure (ESE)***

See chapter 15 and Appendix I.

B. Requirements for Dental Panoramic Units

1. Exposure Reproducibility

a. Procedure: (Same as for the dental intraoral unit) The ion chamber must be secured to the chin rest with adhesive tape for measurement to be taken.

2. Duration of Exposure Cycle

a. Purpose: To ensure that the x-ray generator is producing the exposure time set by the manufacturer.

b. Regulations: The accuracy of the timer should be as stated by the manufacturer.

c. Equipment: Stopwatch or electrometer with small ion chamber. Comment: The MDH model 1515 cannot be used for this test, as it will over-range.

d. Procedure:

(1) Select the most commonly used clinical technique. Make one exposure at this setting.

(2) Start and stop the stopwatch based on the tone which indicates radiation production.

(3) Record the exposure duration from the stopwatch in seconds.

(4) If the electrometer is used, secure the small ion chamber to the patient chin rest, using strong adhesive tape with the probe pointing up. (Since the machine will be moving during the exposure, the ion chamber and converter box must be secure. Dropping the ion chamber can cause extensive damage).

(5) Select the most commonly used clinical technique. Make an exposure at this setting. Record the exposure duration, using the pulse mode of the MDH.

3. ***Linearity of mR/mAs (Same as for dental intraoral unit)***

4. ***Beam Quality- Half Value Layer (HVL) Determination***

a. Purpose: To ensure that the permanently installed filtration at the x-ray tube is maintained at an appropriate level to help minimize patient exposure.

b. Regulations: The minimum value of the HVL shall be as stated in Table B-1, for the operating kVp of the unit.

c. Equipment: Electrometer with small ion chamber and sheets of varying thicknesses of type 1100 alloy aluminum.

d. Procedure:

(1) Secure ionization chamber to the patient chin rest securely, e.g., using strong adhesive tape with the probe pointing up. *[Since the machine will be moving during the exposure, the ion chamber and converter box must be secure]*

(2) Take a reading with the ionization meter in the exposure rate (mR/hr) mode. Record this as the exposure for zero mm of added aluminum.

(3) Tape one mm of Al to the face of the cone, take a second reading and record these results for one mm Al added. Repeat for two, three and four mm of Al. (the four mm test does not need to be done, if three mm cuts the original exposure rate in half).

(4) Remove all Al and take another reading. If the final exposure is not within 2% of the initial reading made with 0 mm Al, repeat the measurement series ensuring that the technique and geometry remain the same throughout the procedure.

(5) Comment: There are procedures to keep the unit from rotating during exposure. However, these are usually invasive, and require the assistance of a dental repair technician. They are not recommended for radiation safety surveys of dental panoramic units.

e. Interpretation of results:

(1) Use the average of the two readings using zero mm Al as the unattenuated value. The HVL may be determined mathematically using logarithmic interpolation or graphically using semi-log paper. Refer to the general radiographic beam quality section for a complete description. Interpolate to find the thickness of Al that reduces the mR output to half of the unattenuated reading. This approximates the HVL of the beam (See Figure B-1).

(2) The HVL must meet FDA standards (Table B-1) for the kVp indicated on the unit.

5. ***X-Ray Beam/Film Slit Alignment***

a. Purpose: To ensure that the x-ray beam and film slit are in alignment.

b. Regulations: The beam dimensions shall not exceed the film slit opening.

c. Equipment: Fluorescent screen or intraoral film and tape.

d. Procedure:

(1) This may be done in real time by using a piece of the fluorescent screen that should be taped to the film holder covering the film slit. Mark the outline of the film slit on the screen. Dim the room lighting and position yourself so that the screen can be seen. Make an exposure and watch for the entire film slit area to glow green.

(2) The film slit alignment may also be recorded on film for documentation as follows:

(a) Tape two pieces of intraoral film across the film slit diagonally, one at the top and one at the bottom of the slit, or a piece of ready pack film across the film holder.

(b) Mark them using a pin to prick the film at the edge of the slit opening and make an exposure only a few seconds in duration.

(c) Develop the film.

e. Interpretation of results:

(1) Fluorescent screen: Entire film slit should be seen.

(2) For film, a diagonal line should be seen across each film from corner to corner or between pin marks.

(3) Record whether satisfactory, or unsatisfactory.

6. ***Entrance Skin Exposure***
(See chapter 15 and Appendix I)

GENERAL DENTAL RADIOGRAPHIC EQUIPMENT DATA FORMS

MEDICAL/DENTAL X-RAY EQUIPMENT DATA
NAVMED 6470/4 (7-80) REPORT SYMBOL MED 6470-15

1. FACILITY IDENTIFICATION

a. FACILITY NAME	b. UIC	
c. MAILING ADDRESS	d. BUILDING	e. ROOM

2. STATUS OF THE EQUIPMENT (INDICATE IF EQUIPMENT IS IN USE OR THE REASON FOR NOT BEING IN USE).

☐ IN USE ☐ TO BE REPAIRED ☐ STORED IN GOOD WORKING CONDITION
☐ NOT IN USE ☐ CANNOT BE REPAIRED ☐ OTHER

3. X-RAY EQUIPMENT IDENTIFICATION

a. PLANT ACCOUNT NUMBER
b. YEAR EQUIPMENT WAS MANUFACTURED
c. INSTALLATION DATE OF EQUIPMENT
d. X-RAY EQUIPMENT IS CERTIFIED: YES ____ NO ____

e. COMPONENT	f. MANUFACTURER	g. MODEL	h. SERIAL NUMBER
1) CONTROL CONSOLE			
2) X-RAY TABLE			
3) X-RAY TUBE ASSEMBLY			
TUBE #1 HOUSING			
TUBE #1 INSERT			
TUBE #1 COLLIMATOR			
IMAGE INTENSIFIER			

☐ CONTINUED ON SEPARTE SHEET

4. TYPE OF X-RAY EQUIPMENT (CHECK AS MANY AS APPROPRIATE)

☐ RADIOGRAPHIC ☐ FIXED ☐ DENTAL INTRAORAL
☐ FLUOROSCOPIC ☐ MOBILE ☐ DENTAL PANOGRAPHIC
☐ COMBINATION R/F ☐ OTHER ________________________

5. GENERATOR (CHECK ONE)

☐ AUTORECTIFIED ☐ THREE PHASE MAXIMUM mA ____ mA
☐ SINGLE PHASE HALF WAVE ☐ CAPACITOR DISCHARGE
☐ SINGLE PHASE FULL WAVE ☐ OTHER (SPECIFY) ________________ MAXIMUM kVp ___ kVp

6. ASSOCIATED EQUIPMENT (CHECK AS MANY AS APPROPRIATE)

☐ AUTOMATIC EXPOSURE CONTROL SYSTEM (LIKE PHOTOTIMER) ☐ PHOTOSPOT CAMERA
☐ SPOT FILM DEVICE ☐ OTHER ______________ ☐ IMAGE INTENSIFIER

7. USE (CHECK ONE)

☐ GENERAL RADIOGRAPHY ☐ MAMMOGRAPHY ☐ OTHER (SPECIFY) ____________________________
☐ CHEST RADIOGRAPHY ☐ TOMOGRAPHY
☐ HEAD RADIOGRAPHY ☐ UROLOGY STUDIES

8. DATE OF LAST RADIATION PROTECTION SURVEY DATE: ☐ UNKNOWN	9.THIS EQUIPMENT REPLACED EQUIPMENT WITH PLANT ACCOUNT NUMBER. ☐ UNKNOWN

10. REPORTED BY: TITLE:	REVIEWED BY:	DATE:

GENERAL REQUIREMENTS FOR RADIOGRAPHIC EQUIPMENT

NAVMED 6470/5 (12-89) REPORT SYMBOL MED 6470-10

1. FACILITY IDENTIFICATION

a. FACILITY NAME	b. UIC	
c. MAILING ADDRESS	d. BUILDING	e. ROOM

2. RADIATION SAFETY EQUIPMENT AND ACCESSORIES

EQUIPMENT OR ACCESSORY	YES	NO	COMMENTS
a. APRONS: ADEQUATE NUMBER			
GOOD CONDITION			
b. GLOVES: ADEQUATE NUMBER			
GOOD CONDITION			
c. GONADAL SHIELDS TYPE: Leaded Rubber Shield			
d. ADEQUATE PATIENT IMMOBILIZATION EQUIPMENT			
e. WARNING LABLELS PRESENT AT CONTROL PANEL (CERTIFIED EQUIPMENT REQUIREMENT)			
f. LIGHTS, METERS IN GOOD WORKING CONDITION.			
g. INTERLOCKS ARE SATISFACTORY.			
h. MECHANICAL/ELECTRICAL STOPS IN GOOD CONDITION			
i. CABLES AND GROUPING IN GOOD CONDITION.			

3. GENERAL CHARACTERISTICS AND PERFORMANCE REQUIREMENTS.

EQUIPMENT OR ACCESSORY	YES	NO	COMMENTS
a. MEANS TO CENTER X-RAY SOURCE OVER IMAGE RECEPTOR IS AVAILALBE (FIXED EQUIPMENT)			
b. TECHNIQUE FACTORS INDICATED BEFORE EXPOSRE.			
c. TECHNIQUE FACTORS VISIBLE AT OPERATORS POSITION.			
d. EXPOSURE TERMINATED AFTER: PRESET: TIME ☐ mAs ☐ NO. OF PULSES ☐ OR RADIAION EXPOSURE TO IMAGE RECEPTOR. ☐			
e. EXPOSURE SWITCH AT ADEQUATE LOCATION.			
f. EXPOSURE SWITCH REQUIRES CONTINUOUS PRESSURE TO OPERATE.			
g. EXPOSURE NOT POSSIBLE WITH THE TIMER IN AN OFF OR ZERO POSITION.			
h. VARIABLE COLLIMATION DEVICES ARE PROVIDED WITH LIGHT FIELDS.			

GENERAL REQUIREMENTS FOR RADIOGRAPHIC EQUIPMENT (CON'T)
NAVMED 6470/5 (12-89) REPORT SYMBOL MED 6470-10

3. GENERAL CHARACTERISTICS AND PERFORMANCE REQUIREMENTS. (CONT)

EQUIPMENT OR ACCESSORY	YES	NO	COMMENTS
i. AUDIBLE INDICATION OF EXPOSURE TERMINATION.			
j. VISIBLE "BEAM ON" INDICATION.			
k. MEANS TO INDICATE WHEN BEAM AXIS IS PERPENDICULAR TO THE IMAGE RECEPTOR.			
l. MEANS OF STEPLESS ADJUSTMENT OF X-RAY FIELD SIZE.			
m. BEAM LIMITING DEVICE NUMERICALLY INDICATES FIELD SIZE.			
n. POSITIVE BEAM LIMITING DEVICE (PBL) IN OPERATING CONDITION.			
o. PBL MODE: ADJUSTMENT POSSIBLE TO FIELDS SMALLER THAN IMAGE RECEPTOR. *			
p. AUTOMATIC RETURN TO PBL WHEN IMAGE RECEPTOR IS CHANGED. *			
q. X-RAY PRODUCTION PREVENTED AT SID'S WHERE OPERATION IS NOT INTENDED.			

*GENERAL PURPOSE X-RAY EQUIPMENT

4. MOBILE X-RAY EQUIPMENT

EXPOSURE SWITCH IS LOCATED SO THAT OPERATOR CAN STAND AT LEAST 6 FEET FROM PATIENT AND USEFUL BEAM.

YES _____ NO _____

5. CHARTS AVAILABLE AND POSTED.

TECHNIQUE CHARTS YES ______ NO _____

RATING CHARTS YES ______ NO _____

6. REMARKS

SURVEYOR:	DATE:

GENERAL REQUIREMENTS FOR RADIOGRAPHIC/DENTAL EQUIPMENT

NAVMED 6470/6 (5-01) REPORT SYMBOL MED 6470-10

I. FACILITY IDENTIFICATION

a. FACILITY NAME	b. UIC	
c. MAILING ADDRESS	d. BUILDING	e. ROOM

II. X-RAY EQUIPMENT IDENTIFICATION

1. X-RAY TUBE HOUSING:

a. MODEL: b. SERIAL NO. c. CERTIFIED: YES _____ NO _____

III. RADIATION EXPOSURE MEASUREMENTS

1. RADIATION EXPOSURE AND TIMER REPRODUCIBILITY.

a. kVp	b. mA	c. Time	d. Distance SID: TDD:

e. MEASUREMENTS

	Exposure	Timer		Exposure	Timer
1	mRad	msec	6	mRad	msec
2	mRad	msec	7	mRad	msec
3	mRad	msec	8	mRad	msec
4	mRad	msec	9	mRad	msec
5	mRad	msec	10	mRad	msec

	Exposure	Timer
mean		
SD		
CV		

2. TIMER ACCURACY

a. kVp	b. mA	c. Distance SID: TDD:

d. MEASUREMENTS

	TIME SETTING	TIME MEASURED	-10%	+10%
1	mSec	mSec		
2	mSec	mSec		
3	mSec	mSec		
4	mSec	mSec		
5	mSec	mSec		

	TIME SETTING	TIME MEASURED	-10%	+10%
6	mSec	mSec		
7	mSec	mSec		
8	mSec	mSec		
9	mSec	mSec		
10	mSec	mSec		

3. LINEARITY OF X-RAY OUTPUT

a. kVp	b. Time	SID	TDD

LINEARITY OF mR/mAS

mA	mRad	mR/mAs	X1-X2	0.1(X1+X2)

OUTPUT LINEARITY TRACKING BY kVP

kVp	mA	Time	mRad	mR/mAs

R value

4. INSTRUMENT USED:

a. TYPE	b. MODEL	c. SERIAL NUMBER	d. CALIBRATION DATE

REMARKS

GENERAL REQUIREMENTS FOR RADIOGRAPHIC/DENTAL EQUIPMENT (CON'T)

NAVMED 6470/6 (5-01) REPORT SYMBOL MED 6470-10

5. KILOVOTAGE ACCURACY

	a. kVp SETTING	b. kVp DETERMINED	c. ACCURACY
1)	kVp	kVp	
2)	kVp	kVp	
3)	kVp	kVp	
4)	kVp	kVp	
5)		kVp	

d. kV CHECKING DEVICE USED:

1) TYPE:

2) MODEL:

3) SERIAL NUMBER:

6. BEAM QUALITY

a. kVp	b. mA	c. Time	d. Distance	OTHER

f. MEASUREMENTS

ADDED FILTRATION	EXPOSURE
mmAl	mR
mmAl	mR
mmAl	mR
mmAl	mR
mmAl	mR
mmAl	mR

g. HVL

mmAl EQUIVALENT

h. EQUIPMENT COMPLIES WITH HVL REQUIREMENTS:

YES _____ NO _____

COMMENTS: ________________

____

Exposure reading that is just less than one-half of initial reading. mR Corresponding Al thickness. mm

Exposure reading that is just greater than one-half of initial reading. mR Corresponding Al thickness. mm

CERTIFIED EQUIPMENT: HVL SHALL NOT BE LESS THAN VALUES LISTED IN TABLE 1 SECTION 1020.30 OF TITLE 21, CHAPTER 1 CFR PART 1020.

OTHER EQUIPMENT: HVL SHOULD BE AS RECOMMENDED IN SECTION 3.2.1. OF NCRP REPORT 33.

REMARKS

REQUIREMENTS FOR DENTAL EQUIPMENT

NAVMED 6470/6 (10-99) REPORT SYMBOL MED 6470-10

IV. OTHER MEASUREMENTS

1. INTRAORAL SYSTEMS

a. CONE LENGTH: [ ]

(SHOULD BE AT LEAST 18 cm (7 INCHES) FOR UNITS OPERATING ABOVE 50 kVp AND AT LEAST 10 cm (4 INCHES) FOR UNITS OPERATING BELOW 50 kVp).

b. MINIMUM TARGET TO SKIN DISTANCE: [ ]

c. BEAM DIAMETER AT END OF CONE: [ ]

2. DENTAL PANORAMIC UNITS

a. SLIT OPENING IS ALIGNED WITH OPENING IN FILM HOLDER:

YES [ ]

NO [ ]

REMARKS

SURVEYOR:	DATE:

Appendix D

Performance Tests for General Fluoroscopic Units

A. General Performance Tests for Fluoroscopic Equipment

1. *kVp Accuracy*

a. Purpose: To verify that tube voltage potential accurately tracks the nominal generator setting.

b. Equipment: Exposure rate compatible kVp meter.

c. Procedure:

(1) Follow the meter manufacturer's instructions.

(2) Some meters may have restricted operating ranges or require specific techniques.

(3) Test the unit in manual kVp mode whenever possible. Test units without manual kVp control at the voltage provided by the automatic brightness control (ABC) system for the kVp meter assembly in the beam.

(4) Record average or effective kVp, as available, when using a meter offering multiple reading formats.

d. Interpretation of Results: Refer units deviating from the criteria in Table 4.1 for adjustment by a qualified service engineer. Proper kVp calibration is critical as it directly influences image quality and patient dose.

2. *Entrance Exposure Rate (EER) Measurements (Typical)*

a. Purpose:

(1) To establish and maintain reasonably low typical exposure rates. JCAHO requires that "typical" fluoroscopic exposure rates be monitored.

(2) To verify long term EER consistency.

(3) To verify proper automatic brightness control of exposure rate with varying image intensifier (II) field size.

b. Equipment: 4 cm Al or 15 cm acrylic phantom, exposure meter & small ion chamber.

c. Procedure:

(1) Refer to the general measurement set up for the tested unit (Figures D-1 and D-2).

(2) Typical and maximum EER measurements can be made with the same basic equipment arrangement.

(3) Place the ion chamber at the location specified by 21 CFR 1020.32(d), (e).

(4) Invert C-arms for testing. This allows for easier phantom placement.

(5) Treat LUA systems as standard/ C-arm hybrids (i.e. meet both conditions).

(6) For adjustable C-arms and LUAs, minimize the focal spot to ion chamber distance.

(7) Place the phantom close to the ion chamber, but far enough away to minimize backscatter to the ion chamber and completely shield the image intensifier. The II is very sensitive. Ensure that it is always shielded by the phantom. 1100 Al alloy or acrylic are acceptable for phantom construction.

(8) Use a phantom to chamber distance of approximately 8 cm. This distance allows for adequate shielding of medium and larger image intensifiers. Very large IIs may require that the

phantom be placed closer to the ion chamber.

(9) Place the grid in the beam path.

(10) Collimate the field to the phantom.

(11) Maintain consistent phantom/ ion chamber/image intensifier positions to assure reproducibility (record distances).

(12) Equipment arrangement modifications are not required for cine EER measurements unless specified by the equipment manufacturer.

d. Measurement Considerations:

(1) Refer to Tables D-1, D-2, & D-3.

(2) Make EER measurements using all available output rate and II size combinations. Include manual and pulse modes, if available. ABC systems will demonstrate different output rates at each II size to compensate for the loss of minification gain.

(3) For manual mode readings, adjust kVp and mA to provide a monitor image brightness equal to that of ABC normal mode.

(4) Make EER measurements with and without the grid in place, as warranted. The grid generally remains in the beam but may be removed if no-grid studies are performed.

(5) Use minimal "beam - on" time to prevent unnecessary x-ray tube wear. A properly functioning detector should settle down to a constant reading within 10 seconds.

(6) Correct raw measurements for temperature, pressure and energy dependence.

(7) Treat LUA systems as standard fluoroscopic systems with minimum source to chamber distances and chamber to II distances of 30 cm. Calculate table transmission factors for maximum kVp and the kVp set by ABC for the phantom. Add table transmission factors to the correction factor list.

(8) If the unit is equipped with high level control (HLC), a distinct tone must be heard when HLC is active.

(9) Some detector systems may not provide accurate EER measurements in pulse mode due to an inability to evaluate sub-second radiation pulses. Some sophisticated systems can be programmed to measure pulse fluoro. For less advanced systems, calculate a mean exposure rate from a single integrated reading of at least 10 seconds at a known pulse rate. During acceptance, evaluate multiple pulse rate settings. During annual evaluations, test the most commonly used pulse rate.

e. Cine Output Measurements:

(1) As most cine systems work at 30 and 60 frs^{-1}, cine EER measurements may suffer from problems similar to those in pulse fluoro.

(2) Bypass the cine camera safety interlock that prevents the unit from working when unloaded unless film frame numbers are to be counted in conjunction with an integrated exposure measurement.

(3) Measure EER using the most commonly used II size and ABC or manual techniques suitable for an average patient (i.e. 4 cm aluminum phantom). Evaluate all available image intensifier sizes during acceptance.

(4) Consider using one of the following measurement techniques:

(a) Program the test frame rate into the detector system (for advanced systems).

(b) Obtain a current mode reading and divide it by the frame rate.

(c) Obtain an integrated output reading for a 10 to 15 second run while actually exposing cine film. Calculate the mean exposure rate using the exposed frame count.

f. Interpretation of Results: Typical EER values should be significantly lower than their maximum output rate counterparts. Use acceptance inspection values to set baselines for future reference. Subsequent annual evaluation results should agree reasonably well with original levels (e.g. ± 10 %).

3. *Maximum Entrance Exposure Rate*

a. Purpose: To prevent excessive exposure to patients subjected to fluoroscopic examinations by verifying that the maximum EER conforms to the limits of 21 CFR.

b. Regulations: 21 CFR Parts 1020.32.(d) and (e) specify maximum exposure rates allowed for fluoroscopic equipment manufactured prior to and after 19 May 1995, respectively. Table D-1 provides a summary of the appropriate limits. Table D-2 indicates the required ion chamber measurement locations based on equipment type.

c. Equipment: 4 cm Al or 15 cm acrylic phantom, 1.6 mm Pb plate, exposure meter with small ion chamber.

d. Procedure:

(1) Set up the fluoro unit, phantom, and ion chamber as for typical EER measurements. Sections A.2.c.(1) to (11) apply.

(2) Place the lead sheet on top of the phantom between the ion chamber and image intensifier.

(3) Make EER measurements in the same manner as outlined in section A.2.d. for all available output modes. For manual modes, set kVp to its maximum level.

(4) Maximum EER measurements need only be made at the largest II size.

(5) Radiation streaming around the lead plate should not be visible during testing.

(6) Warning: Image intensifiers may be irreparably damaged if exposed to unattenuated high energy x-ray beams for extended periods.

e. Interpretation of Results: Ensure that proper ion chamber/lead/II distances are maintained. Maximum EER measurements may be unduly influenced (10 to 15 % above equivalent free in air measurements) by backscatter from the lead sheet if the ion chamber is too close to the phantom/lead assembly. If maximum exposure rates exceed limits set in Table D-1, recommend that the unit be temporarily removed from patient use and recalibrated by a qualified service engineer as soon as possible. If practicable, verify that the new maximum exposure rates are acceptable before the service engineer leaves the facility.

4. *Leakage Through Primary Barrier*

a. Purpose: To verify that the radiation attenuation provided by the II housing is adequate.

b. Equipment: 4 cm Al phantom, 1.6 mm Pb plate, exposure meter with large ion chamber.

c. Procedure:

(1) Arrange the fluoro unit, phantom, and Pb sheet in the same manner as for evaluating maximum EER. Section A.3.(d) applies.

(2) Place the large ion chamber 10 cm beyond the rear surface of the primary barrier (i.e. II housing) with the large flat surface perpendicular to the beam axis.

(3) Irradiate the phantom using the maximum EER technique. Record the radiation level and compare it with the maximum EER recorded previously.

d. Interpretation of Results: Radiation levels at 10 cm beyond the II housing should not exceed 1 $mRhr^{-1}$ for each $Rmin^{-1}$ measured in Section A.3.. Refer units showing excessive radiation transmission for repair by a qualified service engineer.

5. *Beam Quality (Half Value Layer)*

a. Purpose: To verify that the permanently installed filtration in the tube housing is thick enough to minimize patient exposure.

b. Regulations: 21 CFR Part 1020.30(m) specifies the minimum beam quality (HVL) requirements for a range of tube potentials.

c. Equipment: 1100 aluminum alloy HVL sheets, exposure meter with small ion chamber, test stand, 4 cm aluminum phantom.

d. Procedure:

(1) Arrange the unit for largest available II

size, grid in the beam, collimator fully open, and an SID that allows insertion of the test stand between the II and tube.

(2) Using the test stand, place the small ion chamber in the center of the fluoro field, approximately midway between the tube and II.

(3) If the unit allows manual kVp and mA control, use the following procedure:

(a) Manually set kVp = 90.

(b) Place the 4 cm aluminum phantom between the ion chamber and II. Allow some separation between the two to minimize the effect of backscatter.

(c) Under fluoro, collimate the beam to an area just larger than the ion chamber. **Ensure that the phantom always intercepts the beam. Failure to do so may damage the II.**

(d) Set mA to produce an output rate between 300 and 500 mR/min.

(e) Measure the exposure rate without any Al sheets between the tube and ion chamber. Repeat the measurement with 1, 2, 3, 4, and 5 mm Al between the tube and ion chamber.

(4) If the unit does not permit manual technique control (i.e. ABC only), use the following procedure:

(a) Place the Al phantom and collimate the beam per steps 5.d.(3)(b) and (c).

(b) Place all 5 mm Al sheets between the ion chamber and II (e.g. above the Al phantom).

(c) Measure the exposure rate without any Al sheets between the tube and ion chamber, allowing ABC to set kVp for all the aluminum in the beam (i.e. phantom + sheets).

(d) Repeat the measurement with 1 through 5 mm Al between the tube and ion chamber; moving each Al sheet from behind the ion chamber to in front of it. **A constant Al thickness must remain in the beam throughout the procedure to prevent ABC from changing technique factors. Varying factors will lead to erroneous readings.**

(5) Determine HVL for the appropriate voltage potential (set manually or obtained through ABC) mathematically using logarithmic interpolation or graphically using semi-log paper.

e. <u>Interpretation of Results</u>: Table B-1 lists minimum HVLs for various voltage potentials. If the beam does not meet the minimum standard, refer the unit for adjustment by a qualified service engineer. Insufficient filtration may lead to unnecessary patient dose. A unit with a hard beam need not be removed from service. However, a high HVL often indicates the presence of an older tube that may fail shortly thereafter.

6. *Minimum Source to Skin Distance (SSD)*

a. <u>Purpose</u>: To prevent unnecessary patient exposure resulting from an unduly short source to skin distance (SSD).

b. <u>Regulations</u>: 21 CFR Part 1020.32(g) specifies the minimum source to skin distance requirements based on fluoroscopy unit mobility and application.

c. <u>Equipment</u>: Tape measure, etched brass plate, 14” x 17” (35 cm x 43 cm) loaded cassette.

d. <u>Procedure</u>:

(1) For C-arm systems, determine minimum SSD using a tape measure. Measure from the external target position mark to the end of the collimator assembly or spacing cone if permanently installed. Treat LUA systems in the same manner.

(2) For fixed SID, overhead tube systems, measure minimum SSD in the same manner as step (1).

(3) For fixed SSD, undertable tube systems that allow tube access, measure minimum SSD using a tape measure as the distance from the target mark to the tabletop. For systems with variable SSD, set the target to table distance to minimum before measuring.

(4) For fixed SSD, undertable systems without tube access, measure minimum SSD using triangulation as described on page 4 - 1, reference 4. Calculate SSD as:

$$SSD = \frac{OID}{(w_2/w_1)-1}$$

Where OID = Brass plate to film image distance
w_2 = Division length at SID
w_1 = Division length on the plate

e. Interpretation of Results: If the source to skin distance is less than required, refer the unit for adjustment by a qualified service engineer.

7. *Minimum and Maximum Fluoroscopic Image Size (Beam Limitation Devices)*

a. Purpose:

(1) To verify that the fluoroscopic imaging system displays the geometrically appropriate anatomical area of interest.

(2) To prevent unnecessary patient exposure due to irradiating anatomic areas larger than the image receptor.

b. Regulations: 21 CFR Part 1020.32(b) specifies that the minimum radiation field size at maximum SID shall be contained within a square of 5 cm by 5 cm.

c. Equipment: Etched brass plate, 14” x 17” (35 cm x 43 cm) loaded cassette.

d. Procedure:

(1) Arrange the unit for maximum SID, largest available II size, grid in the beam, and all collimators fully open.

(2) Position the brass plate between the tube and image intensifier to fully intercept the beam.

(3) Using appropriate protection, place the cassette as close to the II face as possible with the screen facing the tube. Center the cassette over the II housing assembly.

(4) Expose the cassette for 1 - 2 sec using a low technique (50-60 kVp @ 1 mA).

(5) Close all collimators completely.

(6) Move the cassette over to align the center of the image intensifier with a corner of the cassette.

(7) Re-expose the cassette per step (4).

(8) Measure the dimensions of the darkened areas on the processed film. Correct the measurements if a significant cassette to II distance existed during exposure.

e. Interpretation of Results: If the maximum or minimum field size dimensions exceed tolerance limits, recommend that a qualified service engineer recalibrate the collimators. One method to eliminate the film based beam limitation test procedure is to calibrate the collimator shutters so that they are just visible along the edges of the live image at maximum field size. Once the collimators are properly calibrated, maximum field size conformance can be verified visually on the monitor image.

8. *Fluoro Display Field Alignment*

a. Purpose: To verify that the fluoroscopy beam is properly collimated so that only the tissue volume corresponding to the active entrance area of the II is irradiated, & that the same volume is presented on the monitor.

b. Equipment: Etched brass plate, plastic cylinder with stacked steel balls, 14” x 17” (35 cm x 43 cm) loaded cassette, 2-D level.

c. Procedure:

(1) Arrange the system for minimum SID, largest available II size, grid in the beam, and collimators fully open.

(2) Position the brass plate to obtain an object to image distance (OID) of approx. 30 cm and collimate the image as necessary so that the plate fully intercepts the beam. Place the plastic cylinder on top of the plate, superimposing the plate center and lower steel ball. Using the level, ensure that the horizontal tool surfaces are perpendicular to the beam axis.

(3) Under fluoro, position the plate so that the two steel balls are superimposed in the monitor

image.

(4) Using appropriate protection, place the cassette as close to the II face as possible with the screen facing the tube. Center the cassette over the II housing assembly.

(5) Expose the cassette using normal fluoro to acquire a background film density of approximately 1.2 (≈ 1 sec at 80 kVp and 200 mA). Process the film.

(6) On both the monitor and film images, determine the indicated distance between opposing edges of the viewing field (TV) or radiation field (film) along the two axes on the plate.

(7) Compare the axis lengths in the monitor and film images and calculate the difference between the two as a fraction of SID.

(8) If the unit allows, increase SID to maximum and repeat steps (6) and (7) during acceptance testing. In a properly functioning unit, collimation should track automatically with changing SID.

d. Interpretation of Results: If the difference between the lengths of either monitor/film axis pair exceeds 3 % of SID or if the sum of the differences for both axis pairs exceeds 4 % of SID, refer the system for recalibration by a qualified service engineer.

9. *Beam Central Alignment*

a. Purpose: To verify that the fluoroscopy beam central axis is properly aligned with the center of the image intensifier.

b. Equipment: Etched brass plate, plastic cylinder with stacked steel balls, 2-D level.

c. Procedure:

(1) Complete steps (1) through (3) of the fluoro display field alignment procedure.

(2) If the fluoroscopy beam and II are properly aligned, the two balls will be superimposed and all four axis arms will have equal length. Absence of these two conditions indicates imperfect alignment.

(3) Reposition the plate to provide four equal axis arm lengths. On the monitor image, locate the position of the upper steel ball relative to the pair of etched concentric circles indicating central axis deviations of 1.5 and 3 degrees from the perpendicular.

d. Interpretation of Results: If the beam axis/II misalignment exceeds 1.5 degrees, refer the system for imaging chain repositioning by a qualified service engineer.

10. *Pincushion and "S-ing' Distortion*

a. Purpose: To verify that the fluoroscopic image contains minimal spatial distortion and artifacts.

(1) It is difficult to quantify an amount of acceptable distortion. However, any distortion should be horizontally and vertically symmetrical. It should also be visibly similar for fluoroscopic, cine, and digital spot images produced using the same II.

(2) Two major forms of spatial distortion are pincushion distortion and S-ing. Pincushion is characterized by bowing of peripheral chords into the center of the image. S-ing is characterized by warping of straight lines passing through the center of the image into "S" shapes in the central quarter to third of the image.

b. Equipment: Etched brass plate

c. Procedure:

(1) Verify that the unit meets the standards for fluoro display field and beam central alignment.

(2) Proceed from step (3) of the fluoro display field alignment procedure, Section 8.c.

(3) Remove the plastic cylinder from atop the brass plate. Recollimate the field, if necessary, so that the etched lines forming the axes and rectangular outline are clearly visible in the monitor image.

(4) Observe the image, paying special attention to the effects of excessive spatial distortion.

(5) For adjustable units, move the imaging chain through its full SID range noting changes in the level of distortion with changing SID.

e. Interpretation of Results: If the amounts of pincushion distortion or S-ing exceed the levels prescribed in Table 4.1, refer the system for adjustment by a qualified service engineer. Due to the subjectivity of this test, last hold hard copy reference images showing the level of distortion during acceptance may be invaluable during subsequent periodic testing.

11. *High Contrast Resolution*

a. Purpose: To verify the system's ability to resolve high contrast objects under variable operating conditions and using multiple recording modes.

b. Equipment: High resolution test patterns, 1 mm sheet of 1100 aluminum alloy.

c. Procedure:

(1) Arrange the unit for maximum SID, largest available II size, grid & compression cone out of the beam, and all collimators open.

(2) Attach the test pattern as close to the II face as possible. Place the aluminum sheet between the tube and test pattern so as to fully intercept the beam and collimate the beam to the periphery of the test pattern.

(3) If the unit allows manual kVp and mA control, set kVp = 60 and adjust mA for image brightness that provides the best viewing. If the unit uses ABC, use the kVp and mA provided by the unit for 1 mm Al and test pattern in the beam.

(4) Determine the highest density mesh visible at the image center and periphery. A resolvable mesh should clearly show bright wires separated by dark spaces and be free of Moiré patterns. Due to variable electronic focusing across the II, resolution is typically better in the field center than at the periphery.

(5) Repeat the measurements using all available output rate and II size combinations. Include manual and pulse fluoro, cine, and spot filming (mechanical & digital) during acceptance testing to set image quality baselines for future reference. During periodic testing, evaluate a representative subset of the acceptance group. Table 4 - 1, Number 11 refers.

(6) Make hard copy record images of the test pattern for those modes that allow filming.

d. Interpretation of Results: Table D-4 lists expected high contrast mesh values for image intensified fluoroscopy systems. Individual manufacturers may set more rigorous standards. High contrast resolution for ancillary imaging modes should equal that of their normal dose rate, live fluoro counterparts at the same II size. If the observed resolution does not meet the appropriate standard, recommend that the unit be serviced by a qualified service engineer.

12. *Low Contrast Sensitivity*

a. Purpose: To verify the system's ability to display low contrast information.

b. Equipment: 4 cm Al phantom, multi-perforated Al sheet.

c. Procedure:

(1) Arrange the fluoroscopy unit in the same manner as for making EER measurements, with largest available II size and grid in the beam. Sections A.2.c.(1), (4), and (5) apply.

(2) Place the perforated sheet between the two larger pieces. For units with attached tables, place the combination phantom on the tabletop. For C-arms, place the combination phantom at the same location as for EER measurements.

(3) Collimate the field to the periphery of the phantom, ensuring that all sets of holes are within the image.

(4) If the unit allows for manual kVp and mA control, set kVp to between 85 - 90 and adjust mA for image brightness that provides best viewing. During contrast sensitivity viewing, ensure that enough tube current is applied to prevent the brightness difference from being lost in the image noise. If the unit uses ABC, use the kVp and mA provided by the system for the combination phantom in the beam.

(5) Determine the smallest pair of targets visible with the unaided eye. To count a given target, both circles should be clearly visible against the phantom background.

(6) Repeat the measurement using all available output rate and II size combinations. Include

manual and pulse fluoro, cine, and spot filming (mechanical and digital) during acceptance testing to set image quality baselines for future reference. During periodic testing, evaluate a representative subset of the acceptance group. Table 4 - 1, Number 12 refers.

(7) Make hard copy record images of the visible hole pattern for those modes that allow filming.

d. Interpretation of Results: Image intensified fluoroscopy systems should resolve at least a 3.1 mm diameter object at 2 % nominal subject contrast. Pulse fluoro images may be formed with subsecond photon bursts, making them difficult to assess visually. Low pulse rate images should not be held to the same standards as their continuous beam counterparts. Low contrast sensitivity for cine and mechanical spot film images should equal that of their normal dose rate, live fluoro counterparts at the same II size. If the observed sensitivity does not meet the baseline set at acceptance, refer the unit for adjustment by a qualified service engineer.

13. *Mechanical Spot Film Automatic Exposure Control (AEC)*

a. Introduction:

(1) Automatic exposure control systems attached to fluoroscopy spot film devices provide the same function as their radiographic system counterparts; i.e. compensation for variations in technique factors and patient thickness such that resulting spot films appear with constant, optimal densities.

(2) This evaluation assumes proper operation of the processor used to develop spot films. It also assumes that the AEC system is calibrated for the film/screen combination used with the unit. Therefore, the processor, cassette, and film used for testing should be those actually used during patient imaging. Also, test films should all come from the same emulsion batch.

(3) The following AEC parameters should be evaluated during testing: reproducibility, maximum exposure time, kVp compensation, patient thickness compensation, density control function, and multi - image format (field size) compensation.

b. Equipment: 4 cm Al or 18 cm acrylic phantom, 1.6 mm Pb plate, 14” x 17” (35 cm x 43 cm) loaded cassette, exposure meter with small ion chamber.

c. Procedure:

(1) Arrange the unit in the same configuration used for measuring fluoroscopic EER. Section A.2.c. applies. Ensure that if a grid is used clinically, it is in the beam path during testing.

(2) Record the SID, film/screen combination, and film size used for future testing reproducibility.

(3) Place the loaded cassette in the tower. Program the spot film device for 1:1 image format and move the cassette to the ready position.

(4) Place a 4 cm aluminum or 15 cm acrylic phantom in the beam in the same manner as for measuring EER. Ensure that the phantom covers all the AEC detector cells.

(5) Set the II field to its largest setting, collimating to the phantom periphery if necessary. Fluoro the phantom briefly, allowing the ABC to select an appropriate kVp. Several systems apply the ABC selected kVp directly to the mechanical spot film technique. For those that do not, the fluoro kVp serves as a useful guideline for manual spot film technique programming. For units without ABC, use 80 kVp.

(6) Program the spot filmer as follows: manual kVp and mA selection, exposure time determined by AEC. If more than one detector cell is available and cells can be programmed to work independently, select the center cell, otherwise use all cells simultaneously.

(7) Use a single cassette for testing. This will require processing the film after each exposure.

(8) Measure and record the OD at the center of the field. The OD should be at least 1.2. The radiologist may set a higher baseline density. The range of densities should be within ± 0.15 of the baseline density.

d. *Output Reproducibility:*

(1) Use the basic imaging chain arrangement and phantom thickness. Place the ion chamber along the beam central axis at the phantom

beam entrance surface. Set technique factors as follows: kVp from the fluoro image or, in the absence of ABC, 80 kVp; 200 mA, AEC setting to neutral (0). Substitute an exposed piece of film for fresh film during this test.

(2) Irradiate the phantom, ion chamber and cassette holding exposed film three times. Record the exposure readings and calculate their mean.

(3) All three readings should lie within ± 5% of their mean.

e. *Maximum Exposure Time*:

(1) Use the basic imaging chain arrangement and phantom thickness. Place the lead sheet over the AEC detector fields so that no radiation reaches them. Set technique factors as follows: kVp from the fluoro image or, in the absence of ABC, 80 kVp; 200 mA, AEC setting to neutral (0). Retain the previously exposed film from the reproducibility test.

(2) Irradiate the phantom until AEC shuts off the beam. Record the elapsed mAs.

(3) The beam should terminate prior to the accumulation of 600 mAs.

(4) Replace the exposed film with a fresh piece at the end of the procedure.

f. *kVp Compensation*:

(1) Use the basic imaging chain arrangement and phantom thickness. Set technique factors as follows: 200 mA, AEC setting to neutral (0).

(2) Vary kVp over the clinically used range 70, 80, 90, 100, and 110 kVp, irradiating a separate film for each voltage potential. Record the elapsed mAs for each image and measure the optical density at the center of each processed film using a densitometer.

(3) The densities should lie within the range of ± 0.3 of the baseline density.

g. *Patient Thickness Compensation*:

(1) Use the basic imaging chain arrangement. Set technique factors as follows: kVp from the fluoro image or, in the absence of ABC, 80 kVp; 200 mA, AEC setting too neutral.

(2) Vary phantom thickness over the range: 2, 4 cm Al or 12, 15, and 18 cm acrylic, irradiating a separate film for each phantom thickness. Record the elapsed mAs for each image and measure optical density at the center of each processed film using a densitometer.

(3) The densities should lie within the range of ± 0.3 of the baseline density.

h. *Multi-image Format (Field Size Compensation)*:

(1) Use the basic imaging chain arrangement and phantom thickness. Set technique factors as follows: kVp from the fluoro image, or in the absence of ABC, 80 kVp, 200 mA, AEC to neutral setting (0). Set the imaging format to 4:1.

(2) Irradiate the phantom four times using the 4:1 film format. Record the elapsed mAs for each image and measure the optical density at the center of each darkened field using a densitometer.

(3) The four darkened images should occupy distinct areas on the film with no overlap. The densities should all lie within the range of ± 0.1 of the baseline density.

i. *Density Control Tracking*:

(1) Use the basic imaging chain arrangement and phantom thickness. Place the ion chamber just off the beam central axis at the phantom beam entrance surface. Set technique factors as follows: kVp from the fluoro image or, in the absence of ABC, 80 kVp; 200 mA.

(2) Vary AEC density over the range of available positive and negative settings, exposing a new piece of film for each setting. Record the elapsed mAs, density at the center of each film, and exposure for each image.

(3) The density function should operate as expected; + gives exposure and density increase, - gives exposure and density decrease. The exposure difference per step should meet the manufacturer's specifications or in the absence of such data, be

balanced about the neutral setting output at 25 % per step.

j. Interpretation of Results: Units deviating from the criteria in Table 4.1 should be referred for adjustment by a qualified service engineer. Spot films can constitute a significant fraction of the total radiation output during fluoroscopy procedures. Unfortunately, spot film AEC performance is frequently omitted in periodic testing following acceptance. Proper operation of the spot film device is essential as it frequently provides the only permanent record of the fluoroscopic procedure.

14. *Mechanical Spot Film Alignment*

a. Purpose: To verify the alignment of the x-ray beam with the mechanical spot device.

b. Equipment: 4 cm Al or 18 cm acrylic phantom, 14" x 17" (35 cm x 43 cm) loaded cassette.

c. Procedure:

(1) Arrange the fluoroscopy unit in the same manner as for evaluating mechanical spot film AEC variation with changing field size. Section A.13.(h) applies.

(2) Open the collimators to maximum field size.

(3) Irradiate the phantom using all format sizes not tested during the AEC evaluation. Record each on a separate film. It may be necessary to use more than one cassette size to acquire all possible spot film formats.

d. Interpretation of Results: The resulting darkened fields should occupy distinct areas on the film with no overlap or shadowing among adjacent spot images. Refer spot film units showing adjacent image interference for recalibration by a qualified service engineer.

15. *Entrance Skin Exposures (ESE) (Mechanical and Digital Spot Films)*

Refer to Appendix I for mechanical and digital spot film ESE measurement procedures. Tolerances for both formats are listed in Table 4.1.

B. Additional Performance Tests for Digital Fluoroscopic Equipment

1. *Contrast Response*

a. Purpose: To verify the long term stability of the digital fluoroscopy system's programmed contrast response function.

b. Equipment: 10+ step Al wedge, densitometer

c. Procedure:

(1) Arrange the fluoroscopy unit in the same manner as for evaluating Fluoro Display Field Alignment. Section A.8.(c) applies.

(2) Position the wedge to obtain an object to image distance of approximately 30 cm and collimate the largest II field beam to the wedge periphery so that the test object fully intercepts the beam.

(3) Irradiate the wedge using the default technique factors provided by ABC. Record the image digitally using the last image hold feature.

(4) Record a second image of the wedge using the digital spot film feature and kVp provided by ABC.

(5) Print both images on a common sheet of laser film using 2:1 format. Measure the optical density of each image step. Plot density as a function of wedge thickness for both images.

d. Interpretation of Results: The acceptance curves should resemble the manufacturer's recommended defaults. Some variation may be necessary to accommodate radiologists' preferences. The original curves should be retained as baselines for future reference. Subsequent periodic evaluation curves should not differ significantly from their acceptance counterparts. Systems showing significant contrast response variations should be referred for further analysis and adjustment if necessary.

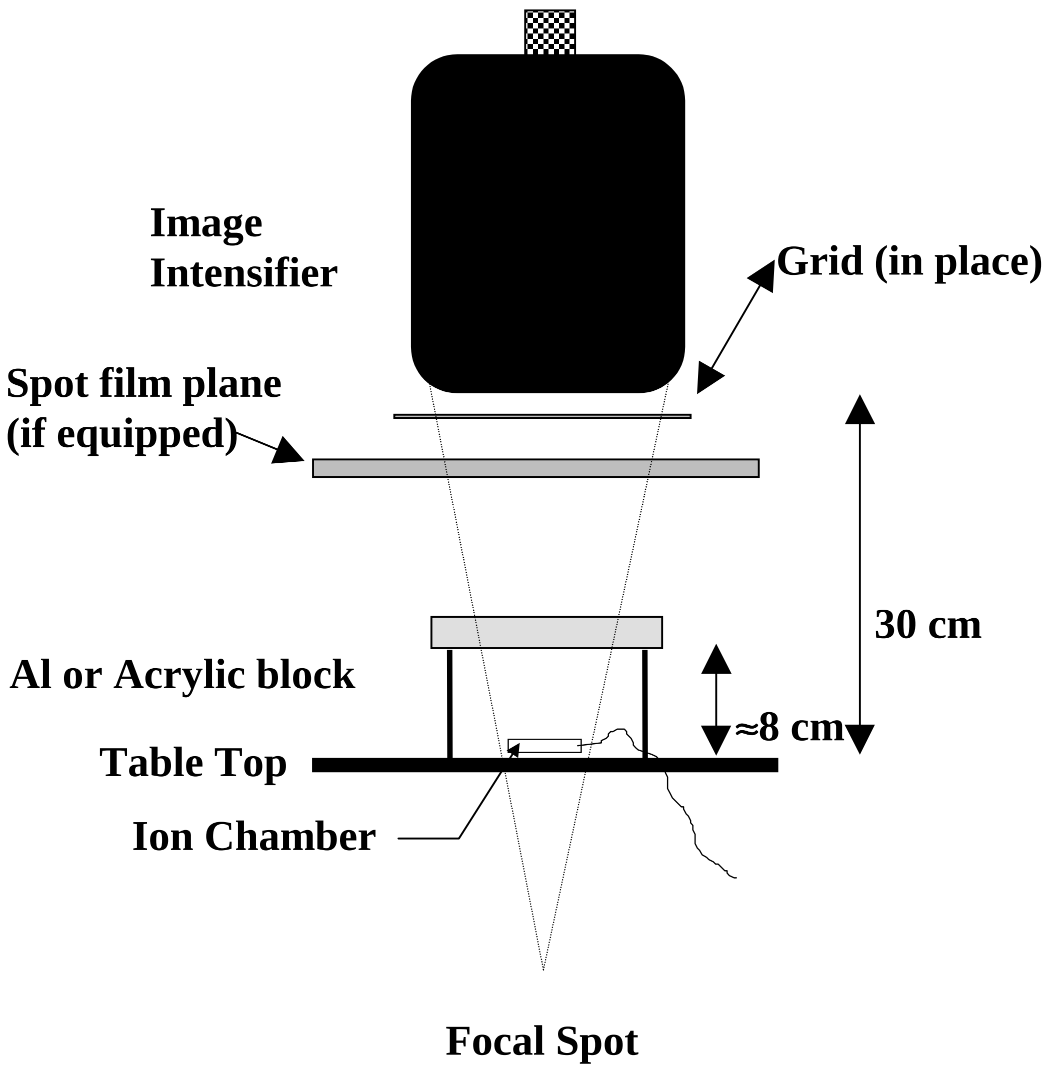


Figure D-1. General Equipment Setup for Fluoroscopic Entrance Exposure Rate Measurement

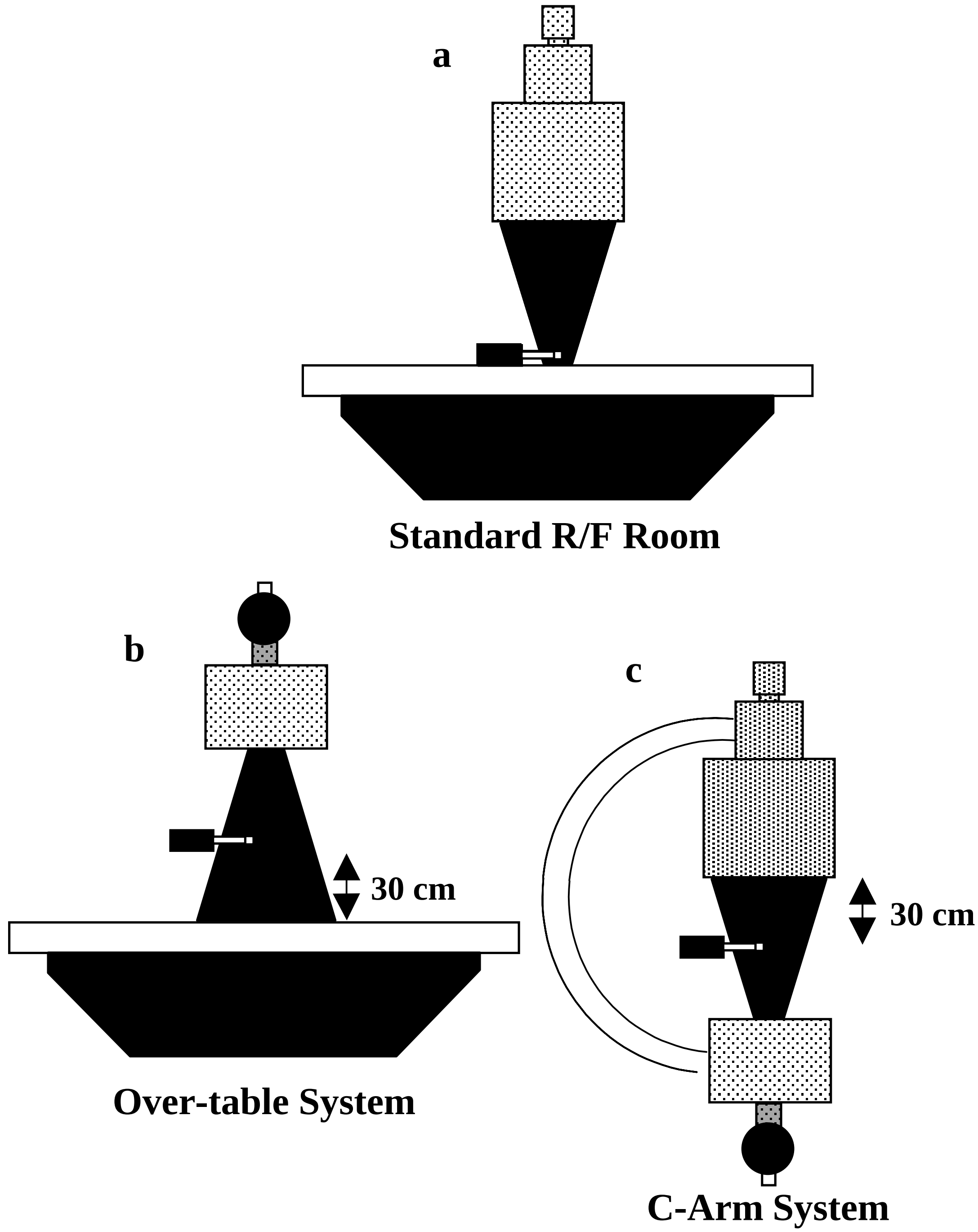


Figure D-2. Entrance Exposure Rate Equipment Setups for Various Fluoroscopic Systems

Table D-1

Entrance Exposure Rate (EER) Measurements

21 CFR Maximum Allowed Entrance Exposure Rates[1]

OUTPUT CONTROL FORM	HIGH LEVEL CONTROL?	LIMIT
Manual (no ABC)	No	5 R min^{-1}
	Yes	5 R min^{-1} in normal mode Unlimited in high level mode
Automatic Brightness Control[2]	No	10 R min^{-1}
	Yes[3]	5 R min^{-1} in normal mode Unlimited in high level mode
Manual +ABC	No	10 R min^{-1} for either mode
	Yes[3]	5 R min^{-1} in normal mode Unlimited in high level mode

[1]Maximum EER levels are set depending on the availability of specific imaging controls and high level control devices on the unit being evaluated.
[2]Any equipment capable of exposure rates greater than 5 R min^{-1} shall be outfitted with ABC.
[3]For systems with ABC and high level control, allow 10 R min^{-1} in normal mode and 20 R min^{-1} in high level mode (From the 1995 Federal Register, for all equipment manufactured after 19 May 95).

Table D-2

Entrance Exposure Rate (EER) Measurements

21 CFR Entrance Exposure Rate Measurement Locations[1]

TUBE POSITION[2]	EER MEASUREMENT POINT
Under table	1 cm above table top.
Above table	30 cm above table with spacer as close to measurement point as possible.
C - arm	30 cm from II face with source at any SID provided that the end of the spacer is not closer than 30 cm from the input surface of the imaging assembly.
Lateral	15 cm from the centerline of the x-ray table and in the direction of the x-ray source with the end of the beam spacer positioned as closely as possible to the point of measurement. If the table is movable, it shall be positioned as closely as possible to the source with the end of the spacer no closer than 15 cm to the centerline of the x-ray table.

[1]Maximum EERs and measurement locations are set by Federal law: 21 CFR Part 1020.32(d), (e)

[2]In some cases it may not be physically possible to place the detector at the prescribed position. In such cases, the chamber should be placed at an appropriate point and the raw measurements inverse square corrected to the prescribed location.

Table D-3

Entrance Exposure Rate (EER) Measurements

Representative EER Values for Various Equipment Types

Procedure	Dose Rate Setting	Image Intensifier Mode (Diameter)	kVp	mA	EER (Output)
Conventional fluoro + ABC tracking from 80 kVp[1]	Med. Detail	Normal (30.5 cm)	81	0.6	1.150 R min^{-1}
		Mag 1 (22.9 cm)	81	1.2	2.255 R min^{-1}
		Mag 2 (15.2 cm)	81	2.4	4.485 R min^{-1}
		Mag 3 (11.4 cm)	84	3.6	6.840 R min^{-1}
Digital fluoro + ABC tracking from 80 kVp[1]	Med. Detail	Normal (30.5 cm)	80	0.6	1.245 R min^{-1}
		Mag 1 (22.9 cm)	80	1.3	2.485 R min^{-1}
		Mag 2 (15.2 cm)	80	2.7	4.925 R min^{-1}
		Mag 3 (11.4 cm)	85	3.5	7.005 R min^{-1}
Continuous fluoro + ABC[2]	Normal	Normal (22.9 cm)	69	2.1	1.30 R min^{-1}
		Mag 1 (15.2 cm)	71	2.9	1.86 R min^{-1}
		Mag 2 (10.2 cm)	70	3.7	2.31 R min^{-1}
Pulse fluoro (4 Hz) + ABC[2]	Normal	Normal (22.9 cm)	69	2.1	0.26 R min^{-1}
		Mag 1 (15.2 cm)	70	2.9	0.35 R min^{-1}
		Mag 2 (10.2 cm)	70	3.8	0.46 R min^{-1}
Pulse fluoro (4 Hz) + ABC[2]	Low	Normal (22.9 cm)	72	0.6	0.04 R min^{-1}
		Mag 1 (15.2 cm)	77	0.7	0.05 R min^{-1}
		Mag 2 (10.2 cm)	81	0.7	0.06 R min^{-1}
Cine, Adult Coronary[3] (30 fr s^{-1} and 4 msec fr^{-1})	Normal	Normal (23.0 cm)	58	500	17.6 mR $frame^{-1}$ ($\tilde{}$ 32 R min^{-1})

[1] 1996 Naval Medical Center, San Diego; G.E. Advantx RF room with mechanical & digital spot film.
[2] 1995 Naval Medical Center, San Diego; OEC 9600 with surgical and pulse fluoro packages.
[3] 1995 Naval Medical Center, San Diego; Phillips Integris H3000 single plane cardiac catheterization lab.

Table D-4

High Contrast Resolution Measurements

Expected High Contrast Mesh Values for
Image Intensified Fluoroscopic Imaging Systems[1]

Nominal II Diameter	Visible Mesh Number	
	Field Center	Field Edge
> 12 inches (> 30.5 cm)	20	20
12 inches (30.5 cm)	24	20
9 inches (22.9 cm)	30, (24)[2]	24, (20)[2]
6 inches (15.2 cm)	40, (30)[2]	30, (24)[2]
4.5 inches (11.4 cm)	50	40

[1]Values correspond to a G.E. Medical Systems Advantx RF system using low detail conventional fluoroscopy + ABC at 60 kVp, 1 mm Al in the beam, maximum SID, and no grid in the beam. Mesh numbers determined visually using live television image.
[2]Values from RMI® 141 and 141-H test pattern instructions for conventional fluoroscopy.

GENERAL FLUOROSCOPIC EQUIPMENT DATA FORMS

MEDICAL/DENTAL X-RAY EQUIPMENT DATA
NAVMED 6470/4 (7-80) REPORT SYMBOL MED 6470-15

1. FACILITY IDENTIFICATION

a. FACILITY NAME	b. UIC	
c. MAILING ADDRESS	d. BUILDING	e. ROOM

2. STATUS OF THE EQUIPMENT (INDICATE IF EQUIPMENT IS IN USE OR THE REASON FOR NOT BEING IN USE).

☐ IN USE ☐ TO BE REPAIRED ☐ STORED IN GOOD WORKING CONDITION
☐ NOT IN USE ☐ CANNOT BE REPAIRED ☐ OTHER

3. X-RAY EQUIPMENT IDENTIFICATION

a. PLANT ACCOUNT NUMBER	
b. YEAR EQUIPMENT WAS MANUFACTURED	
c. INSTALLATION DATE OF EQUIPMENT	

d. X-RAY EQUIPMENT IS CERTIFIED: YES ____ NO ____

e. COMPONENT	f. MANUFACTURER	g. MODEL	h. SERIAL NUMBER
1) CONTROL CONSOLE			
2) X-RAY TABLE			
3) X-RAY TUBE ASSEMBLY			
TUBE #1 HOUSING			
TUBE #1 INSERT			
TUBE #1 COLLIMATOR			
IMAGE INTENSIFIER			

☐ CONTINUED ON SEPARTE SHEET

4. TYPE OF X-RAY EQUIPMENT (CHECK AS MANY AS APPROPRIATE)

☐ RADIOGRAPHIC ☐ FIXED ☐ DENTAL INTRAORAL
☐ FLUOROSCOPIC ☐ MOBILE ☐ DENTAL PANOGRAPHIC
☐ COMBINATION R/F ☐ OTHER ________________________

5. GENERATOR (CHECK ONE)

☐ AUTORECTIFIED ☐ THREE PHASE MAXIMUM mA ____ mA
☐ SINGLE PHASE HALF WAVE ☐ CAPACITOR DISCHARGE
☐ SINGLE PHASE FULL WAVE ☐ OTHER (SPECIFY) ________________ MAXIMUM kVp ___ kVp

6. ASSOCIATED EQUIPMENT (CHECK AS MANY AS APPROPRIATE)

☐ AUTOMATIC EXPOSURE CONTROL SYSTEM (LIKE PHOTOTIMER) ☐ PHOTOSPOT CAMERA
☐ SPOT FILM DEVICE ☐ OTHER ______________ ☐ IMAGE INTENSIFIER

7. USE (CHECK ONE)

☐ GENERAL RADIOGRAPHY ☐ MAMMOGRAPHY ☐ OTHER (SPECIFY) ____________________________
☐ CHEST RADIOGRAPHY ☐ TOMOGRAPHY ____________________________
☐ HEAD RADIOGRAPHY ☐ UROLOGY STUDIES

8. DATE OF LAST RADIATION PROTECTION SURVEY DATE: ☐ UNKNOWN	9.THIS EQUIPMENT REPLACED EQUIPMENT WITH PLANT ACCOUNT NUMBER. ☐ UNKNOWN

10. REPORTED BY: TITLE:	REVIEWED BY:	DATE:

GENERAL REQUIREMENTS AND PERFORMANCE TESTS FOR FLUOROSCOPIC EQUIPMENT

NAVMED 6470/7 (10-99) REPORT SYMBOL MED 6470-10

I. FACILITY IDENTIFICATION

1. FACILITY NAME	2. UIC	3. BUILDING	4. ROOM

5. MAILING ADDRESS

II. X-RAY EQUIPMENT IDENTIFICATION

1. X-RAY MACHINE: CERTIFIED YES _____ NO ______

2. X-RAY TUBE:
   - a. MANUFACTURER:
   - b. MODEL:
   - c. SERIAL NUMBER:

3. IMAGE DEVICE:
   - a. TYPE:
   - b. SERIAL NUMBER:

III. OPERATIONAL AND RADIATION SAFETY CHARACTERISTICS

1. PROTECTION DEVICES	YES	NO
a. LEAD GLOVES AND APRONS: 0.25 mm LEAD EQUIVALENCE OR MORE.		
b. TOWER APRON; 0.25 mm LEAD EQUIVALENCE OR MORE.		
c. BUCKY SLOT COVER; 0.25 mm LEAD EQUIVALENCE OR MORE.		
d. EXPOSURE SWITCH REQUIRES CONTINUOUS PRESSURE TO OPERATE.		
e. FLUOROSCOPY TUBE DOES NOT PRODUCE X-RAYS UNLESS THE IMAGE DEVICE ASSEMBLY IS IN POSITION INTERCEPTING THE X-RAY BEAM.		
f. THE X-RAY FIELD DOES NOT EXTEND BEYOND THE IMAGE DEVICE ASSEMBLY.		
g. SHUTTERS CLOSE OR REDUCE THE X-RAY FIELD TO NO MORE THAT 5 x 5 cm. AT MAXIMUM SID.		
h. CUMULATIVE "ON TIME" (5 MIN MAX) TIMER IS PROVIDED AND IS MANUALLY RESET.		
i. AUDIBLE SIGNAL INDICATES COMPLETION OF PRESET CUMULATIVE TIME.		
j. HIGH LEVEL CONTROL, IF AVAILABLE, REQUIRES THE OPERATOR TO APPLY CONTINUOUS PRESSURE AND AN AUDIBLE SIGNAL INDICATES CONTROL IS BEING USED.		
k. CERTIFIED EQUIPMENT: LENGTH OR WIDTH OF X-RFAY FIELD IN THE PLANE OF IMAGE RECEPTOR DOES NOT EXCEED VISIBLE AREA BY MORE THAN 3% OF SID.		
l. SPOT FILM DEVICE IS FUNCTIONING SATISFACTORILY.		

2. REMARKS-

GENERAL REQUIREMENTS AND PERFORMANCE TESTS FOR FLUOROSCOPIC EQUIPMENT (CON'T)

NAVMED 6470/7 (10-99) REPORT SYMBOL MED 6470-10

IV. PERFORMANCE TESTS

1. KILOVOTAGE ACCURACY

	a. kVp SETTING	b. kVp DETERMINED	c. ACCURACY
1)	50 kVp	kVp	
2)	60 kVp	kVp	
3)	70 kVp	kVp	
4)	80 kVp	kVp	
5)	90 kVp	kVp	
6)	100 kVp	kVp	
7)	110 kVp	kVp	
8)	120 kVp	kVp	
9)		kVp	
10)		kVp	

d. kV CHECKING DEVICE USED:

1) TYPE:

2) MODEL:

3) SERIAL NUMBER:

2. TYPICAL ENTRANCE EXPOSURE RATE

IMAGE SIZE:	Phantom:	b. kVP	c. mA	d. R/MIN
	1. MANUAL:			
	2. AUTOMATIC BRIGHTNESS CONTROL:			
	3. HIGH LEVEL CONTROL			
	4. PULSE FLUOROSCOPY			
	5. CINE			
IMAGE SIZE:	Phantom:	b. kVP	c. mA	d. R/MIN
	1. MANUAL:			
	2. AUTOMATIC BRIGHTNESS CONTROL:			
	3. HIGH LEVEL CONTROL			
	4. PULSE FLUOROSCOPY			
	5. CINE			
IMAGE SIZE:	Phantom:	b. kVP	c. mA	d. R/MIN
	1. MANUAL:			
	2. AUTOMATIC BRIGHTNESS CONTROL:			
	3. HIGH LEVEL CONTROL			
	4. PULSE FLUOROSCOPY			
	5. CINE			
IMAGE SIZE:	Phantom:	b. kVP	c. mA	d. R/MIN
	1. MANUAL:			
	2. AUTOMATIC BRIGHTNESS CONTROL:			
	3. HIGH LEVEL CONTROL			
	4. PULSE FLUOROSCOPY			
	5. CINE			

SURVEYOR: DATE:

GENERAL REQUIREMENTS AND PERFORMANCE TESTS FOR FLUOROSCOPIC EQUIPMENT (CON'T)

NAVMED 6470/7 (5-01) REPORT SYMBOL MED 6470-10

IV. PERFORMANCE TESTS (CONTINUED)

3. MAXIMUM ENTRANCE EXPOSURE RATE

IMAGE SIZE:	Phantom:	b. kVP	c. mA	d. R/MIN
1. MANUAL:				
2. AUTOMATIC BRIGHTNESS CONTROL:				
3. HIGH LEVEL CONTROL				
4. PULSE FLUOROSCOPY				
5. CINE				

MAXIMUM ENTRANCE EXPOSURE RATE SHOULD NOT BE MORE THAN:

10 R/MIN - UNCERTIFIED EQUIPMENT

5 R/MIN - CERTIFIED EQUIPMENT AND ALL EQUIPMENT WITH HIGH LEVEL CONTROL, WHEN IT IS NOT IN USE.

4 RADIATION TRANSMITTED THROUGH PRIMARY BARRIER

a. Technique used to obtaine maximum entrance exposure rate			b. MEASUREMENT (mR/hr)
MODE	kVp	mA	

INSTRUMENT USED

a. TYPE	b. MODEL	c. SERIAL NUMBER	d. CALIBRATION DATE
RADCAL MDH			DATE:

5. BEAM QUALITY

	b. I.I. SIZE	c. Mode	d. kVP	e. mA	f. OTHER
a. MEASUREMENTS					

	ADDED FILTRATION	EXPOSURE
1		
2		
3		
4		
5		

g. HVL: __________mm Al. EQUIVALENT.

h. EQUIPMENT COMPLIES THE HVL REQUIREMENTS:

YES ____ NO ____

Exposure reading that is just less than one-half of initial reading. ______ mR Corresponding Al thickness. ______ mm

Exposure reading that is just greater than one-half of initial reading. ______ mR Corresponding Al thickness. ______ mm

6. MINIMUM SSD

MINIMUM SOURCE TO SKIN DISTANCE _______ CM. MODE OF DETERMINATION: TRAIANGULATION OR TAPE MEASURE

7. BEAM LIMITATION

a. MINIMUM FIELD SIZE ____________ MAX SID: LARGEST I.I. SIZE:

b. MAXIMUM FIELD SIZE ____________

8. FLUOROSCOPIC DISPLAY SIZE

	VERTICAL AXIS (cm)	HORIZONTAL AXIS (cm)	SID
VIEWING FIELD (TV)			
RADIATION FIELD (FILM)			
ALIGNMENT DIFF (% OF SID)			

SUM OF ALIGNMENT DIFFERENCES EXPRESSED AS A PERCENTAGE OF THE SID ______

9. BEAM CENTRAL ALIGNMENT

MINIMUM SID	MAXIMUM I.I. SIZE

IS BEAM AXIS/I.I. MISALIGNMENT LESS THAN OR EQUAL TO 1.5 DEGREES YES ______ NO ______

GENERAL REQUIREMENTS AND PERFORMANCE TESTS FOR FLUOROSCOPIC EQUIPMENT (CON'T)

NAVMED 6470/7 (10-99) REPORT SYMBOL MED 6470-10

IV. PERFORMANCE TESTS (CONTINUED)

10. SPATIAL DISTORTION

FLUOROSCOPIC MODE: MANUAL OR ABC		LARGEST IMAGE INTENSIFIER SIZE	
a. PIN-CUSHION DISTORTION	YES	NO	
b. "S-ING" DISTORTION	YES	NO	

11. HIGH CONTRAST RESOLUTION

	NUMBER OF LINE PAIRS VISIBLE AT EDGE/CENTER				MAX SID	
FLUOROSCOPIC MODE (I.I. SIZE)						
MANUAL MODE						
AUTOMATIC BRIGHTNESS CONTROL						
HIGH LEVEL CONTROL						
PULSED FLUOROSCOPY						
CINE						
SPOT FILMING (MECHANICAL)						
SPOT FILMING (DIGITAL)						

12. LOW CONTRAST SENSITIVITY

	HOLE SIZE VISIBLE				MAX SID	
FLUOROSCOPIC MODE (I.I. SIZE)						
MANUAL MODE						
AUTOMATIC BRIGHTNESS CONTROL						
HIGH LEVEL CONTROL						
PULSED FLUOROSCOPY						
CINE						
SPOT FILMING (MECHANICAL)						
SPOT FILMING (DIGITAL)						

IS 3.1 mm TEST HOLE AT 2% CONTRAST VISIBLE FOR ALL MODES EXCEPT PULSE FLUORO YES / NO

13. AUTOMATIC EXPOSURE CONTROL (AEC) SYSTEM

SID:	FLIM/SCREEN COMBINATION:	FILM SIZE:	

a. OPTICAL DENSITY EVALUATION:

kVp	mA	Detector Cell	AEC Setting	Phantom Thickness	Image Number	Elapsed mAs	Measured OD

b. OUTPUT REPRODUCIBILITY

Imaging Mode	kVp	mA	AEC Setting	SID	

Detector Cell		Reading 1	Reading 2	Reading 3	Mean	-5%	+5%
	Output (mR)						

ARE ALL VALUES WITHIN +/- 5% OF MEAN YES / NO

c. BACK-UP TIMER

Imaging Mode	kVp	mA	Lead Thickness	AEC Setting	SID

Detector Cell	Elapsed mAs	DOES THE BEAM TERMINATE PRIOR TO 600 mAs	
		YES	NO

d. kVp COMPENSATION

mA	Phantom Thickness	AEC Setting	

kVp	Elapsed mAs	Optical Density

Density Range

Do all densities lie within +/- 3% of baseline density determined in 13a. Yes / No

IV. PERFORMANCE TESTS (CONTINUED)

13. AUTOMATIC EXPOSURE CONTROL (AEC) SYSTEM (CONTINUED)

e. PATIENT THICKNESS COMPENSATION

kVp	mA	Imaging Mode	

Phantom Thickness	Elapsed mAs	Optical Density

Density Range

Do all densities lie within +/- 0.3 of baseline density determined in 13a. Yes / No

f. MULTI IMAGE FORMAT (FIELD SIZE COMPENSATION)

Imaging Mode	kVp	mA	Type and thickness of Phantom	AEC Setting	Image Format

Quadrant	Elapsed mAs	Measured OD

Density Range

Do all densities lie within +/- 0.3 of baseline density determined in 13a. Yes / No

g. DENSITY TRACKING

Imaging Mode	kVp	mA	Type and thickness of Phantom	

Density Setting	Elapsed mAs(I)	Measured OD (OD(i))	Relative to Normal mAs(I)/mAs(n)	Relative to Normal OD(i)-OD(n)	% difference from neutral setting OD

14. MECHANICAL SPOT FILM ALIGNMENT

IMAGE FORMAT	OVERLAPPING OR SHADOWING
1:1	YES / NO
4:1	YES / NO
9:1	YES / NO

MAX I.I. SIZE

15. CONTRAST RESPONSE (DIGITAL SYSTEMS)

	IMAGE GENERATED BY IMAGE HOLD	DIGITAL SPOT FILM
STEP 1 OD		
STEP 2 OD		
STEP 3 OD		
STEP 4 OD		
STEP 5 OD		
STEP 6 OD		

SID OF 30 cm
MAX I.I. SIZE

Plot density as a function of wedge thickness for both images and compare

IV. PERFORMANCE TESTS (CONTINUED)

CONCLUSIONS

	YES	NO
a. MAXIMUM ENTRANCE EXPOSURE RATE DOES NOT EXCEED 10 R/MIN UNDER NORMAL NORMAL CONDITIONS (NOT EQUIPPED WITH HIGH LEVEL CONTROL).		
b. MAXIMUM ENTRANCE EXPOSURE RATE DOES NOT EXCEED 5 R/MIN WHEN EQUIPPED WITH HIGH LEVEL CONTROL.		
c. THE SOURCE TO SKIN DISTANCE FOR UNDER TABLE FLUOROSCOPIC TUBE IS NOT LESS THAN 12".		
d. RADIATION TRANSMITTED THROUGH PRIMARY BARRIER DOES NOT EXCEED 1 Mr/HR AT 10 cm FROM PRIMARY BARRIER REAR SURFACE.		
e. THE HALF-VALUE LAYER WAS DETERMINED TO BE ________ IN mm Al EQUIVALENTS.		
f. EQUIPMENT COMPLIES WITH HALF-VALUE REQUIREMENTS.		
g. kVp DETERMINED TO BE WIHTIN +/- 5 % OF NOMINAL SETTING OR READOUT.		
h. PERFORMANCE TESTS ON IMAGE INTENSIFIER WERE SATIFACTORY.		
I. AEC OUTPUT REPRODUCTILITY FOR SPOT FILM DEVICE IS WITHIN +/- 5% OF MEAN.		
j. OPTICAL DENSITY RANGES FOR SPOT FILM AEC EVALUATION TESTS WITHIN ACCEPTABLE LIMITS.		

SURVEYOR:	DATE:

Appendix E

Performance Tests for Linear Tomographic Units

A. Performance Tests for Tomographic Equipment

1. *Tomographic Cut Level Indicator*

a. Purpose: To determine the accuracy of the tomographic cut level indicator. Inaccuracy or nonreproducible results may produce a tomographic image missing information of diagnostic interest.

b. Regulations: The agreement of the indicated and the expected section levels should be within +/- 5mm for add-on equipment, +/- 1mm for dedicated tomographic units (see manufacturer specifications).

c. Equipment:

(1) 45 degree tomographic wedge with radiopaque centimeter scale or equivalently,

(2) Tomographic Test Tool

(3) Two 5mm thick Plexiglas attenuator blocks.

d. Procedure:

(1) Prepare the equipment to be tested for operation in the tomographic imaging mode. Select the most commonly used tomographic motion, exposure angle and sweep as clinically employed on the equipment.

(2) Load a cassette (11x14 inch or larger) in the cassette tray so the long axis is parallel with the long dimension of the x-ray table.

(3) Position the test wedge on the tabletop, linear systems, position the device so the number scale is perpendicular to the direction of motion. Position the Plexiglas attenuators on each side of the wedge. Set the field size to the cassette dimensions.

(4) If the RMI phantom is used, it should be centered over the film cassette with the step numbers perpendicular to the direction of motion. The RMI tool comes with 4, 2, and 1 cm spacers, allowing one to check any tomographic level from 1 to 80 mm.

(5) Using the means available with the equipment, set the cut level indicator to provide a cut level of 15 cm anterior to the tabletop.

(6) Set technique of 60 kVp (or less) and 50 mAs.

(7) Make a tomographic exposure and process the exposed film. Evaluate the film for the necessary density to interpret the numerical readings of the centimeter scale.

(8) Record all parameters used (exposure technique, tomo unit settings).

(9) Repeat the test for cut levels of 3, 5, and 7 cm and for other exposure angles, sweep speeds and motions clinically used.

e. Interpretation Of Test Results:

(1) View the processed film on a radiographic illuminator. Determine on the image of the 45^{o} tomographic test wedge the wire in the test image that is in sharpest focus. From the scale determine the centimeter height to which this corresponds. Record this value. Compare the measured value of the cut level to the indicated value and record the difference.

(2) Determine on the image of the RMI test tool the numeral that is in sharpest focus. Normally, this number will be bordered by tow numbers which are partially blurred while the rest of the numerals will show ever increasing blurring. The

number in sharpest focus corresponds to the cut height (when the spacer height, 10, 20, or 40 mm is factored in.) Record this value.

2. *Tomographic Exposure Angle:*

a. Purpose: Exposure angle is inversely related to cut thickness. Tomographic sections that are too thick or too thin to often reveal little of diagnostic interest and may result in inaccurate or non-reproducible images. This test will determine the exposure angle during a tomographic exposure and compare it with the indicated exposure angle.

b. Regulation: The agreement of the indicated and the measured exposure angles should be within +/- 5 degrees for units operating at angles greater than 30 degrees; for smaller tomographic angles, the agreement between indicated and measured should be closer. For units employing symmetric motion at wide angles, the symmetry of exposure angle should be within 5 degrees with respect to the centerline

c. Equipment:

(1) 45 degree tomographic wedge with radiopaque centimeter scale; may be difficult to obtain. Biomedical Engineering technicians (BMETs)should have one you can ask to borrow.

(2) Two 5mm thick Plexiglas attenuator blocks.

d. Procedure:

(1) Select the most commonly used tomographic motion, exposure angle and sweep speed used for clinical tomographic imaging.

(2) With the x-ray tube perpendicular to the table or using the equipment's centering light, position the tomographic test wedge in the center of the field so the 12.5 cm scale marker is coincident with the central ray. For linear systems, orient the wedge so the scale is perpendicular to the direction of the tube motion. Place the Plexiglas attenuators on each side of the wedge.

(3) Place at least a 11x24 inch cassette in the cassette tray oriented with the long axis along the long axis of the table.

(4) Select technique of 60 kVp and approximately 50 mAs.

(5) Select a cut level of 12.5 cm and make the tomographic exposure.

(6) Process the film and record all techniques and tomographic parameters.

(7) Repeat the procedure for other exposure angles and tomographic motions used clinically.

e. Interpretation Of Results:

(1) In the tomogram, the image of the long diagonal wire will appear as two blurred triangles, see Figure E-1. The apex of each triangle will appear in sharp focus at the level of cut. On the image, reconstruct with a ruler and film marking pencil the outline of these triangles. Select one of the triangles and using the reference scale as a guide, draw a baseline to the triangle. From the scale markings, determine the distance from the apex of the triangle drawn to the baseline. Using a centimeter ruler, measure the width of the reconstructed triangle at the drawn baseline. Let the distance from the triangle baseline to the apex be "b", and the baseline width be "c". The tomographic exposure angle "α," is then determined by:

$$\alpha = 2 \tan^{-1} (c/2b)$$

Calculate the quantity, (c/2b), and with the aid of Figure E-2, or using your calculator, determine the value of $\tan^{-1}$ that corresponds with that quantity. Tan^{-1} (c/2b) corresponds to one-half the tomographic exposure angle α when the value "c" is used in the calculation and to the tomographic exposure half angles $\alpha 1$ and $\alpha 2$ where c_1 and c_2 are used in the calculation respectively.

(2) The exposure angle should also be evaluated for symmetry about the midline of the exposure. This may be done by constructing a perpendicular line for the baseline of the reconstructed triangle through the apex of the triangle and calculating the exposure half angle as:

$\alpha 1 = 2 \tan^{-1} (c1/2b)$ and $\alpha 2 = 2 \tan^{-1} (c2/2b)$

3. *Tomographic Cut Thickness*

a. Purpose: To visualize different anatomical features, tomographic sections of different thicknesses are used. The tomographic unit's ability to reproduce consistent cut thicknesses is essential in meeting this requirement.

b. Regulation: This characteristic varies with type of tomographic motion, exposure angle and uniformity. Tolerance limits should be determined when the machine is acceptance tested. These results may then be used for future comparison tests. Manufacturer specifications may also be used for comparison test evaluation.

c. Equipment:

(1) 45 degree tomographic wedge with radiopaque centimeter scale.

(2) Two 5mm thick Plexiglas attenuator blocks.

d. Procedure:

(1) Insert 11x14 inch cassette (minimum) into cassette tray.

(2) With the x-ray tube perpendicular to the tabletop or using the system's centering light, position the tomographic test tool so the 12.5 cm mark on the scale is coincident with the central ray. For linear systems, the test tool should be oriented so that the scale is parallel to the direction of the tube travel. Place the Plexiglas attenuators on each sides of the wedge

(3) Select the most commonly used tomographic motion, sweep speed and exposure angle used clinically. Select cut level of 12.5 cm.

(4) Select exposure technique of 60 kVp and 30 mAs.

(5) Make the exposure and process the film. Record all tomographic setup parameters.

(6) Repeat #5 for all commonly used tomographic motions, sweep speeds and exposure angles.

e. Interpretation Of Results:

(1) View each film on a radiographic illuminator. The image of the wires on the tomographic scale will be in varying degrees of focus. The wire in the sharpest focus is the level of the cut plane. To either side of this wire the focus will decrease.

(2) Determine the distance on both sides from the sharpest focus point over which the wire images remain in reasonable focus. The sum of each distance is the thickness of the cut plane.

4. *Flatness of the Tomographic Plane*

a. Purpose: The intent of tomography is to better visualize a plane of the patient's anatomy. Mechanical instability in the tomographic unit may result in non-flat sectional images. This loss of flatness may be interpreted incorrectly as an unusual anatomical configuration in the patient. This test will determine the flatness of the tomographic cut plane.

b. Regulation: Add on tomographic devices to routine x-ray units and linear tomographic units should have a cut plane flatness of +/- 3mm. Dedicated tomography units should have a cut plane flatness of +/- 2mm

c. Equipment:

(1) 45 degree tomographic wedge with radiopaque centimeter scale.

(2) Two 5mm thick Plexiglas attenuator blocks.

d. Procedure:

(1) Place 14x17 inch cassette into tray.

(2) With the x-ray beam perpendicular to the tabletop, adjust the field size to the cassette dimensions. Using the light localizer, position the test wedge in the upper left quadrant of the light field so that the 12 cm point on the cm scale is in the approximate center of the quadrant. For linear

systems, the wedge scale should be parallel to the direction of the tube travel. Place the Plexiglas attenuators on each side of the wedge

(3) Select the tomographic motion, sweep speed and exposure angle most commonly used. For ease in test interpretations, the largest exposure angle available should be used.

(4) Set the cut level indicator to 12 cm.

(5) Set technique for 60 kVp and approximately 50 mAs.

(6) Make and exposure and process the film. Identify parameters used and quadrant on film and data sheet.

(7) Make three additional tomographic test films but move the wedge to the center of the remaining quadrants between exposures.

(8) Repeat test procedure for other tomographic motions, sweep speeds and exposure angles clinically used.

e. <u>Interpretation Of Results</u>:

(1) View the complete test films on a radiographic illuminator. For each test film, determine the scale marker that is in maximum focus (cut level). The point of the scale that is in the sharpest focus should be the same regardless of the quadrant in which the test device was imaged.

5. *Uniformity Of Tomographic Exposure*

a. <u>Purpose</u>: A non-uniform exposure over the arc of motion of the tomographic unit yields an effective tomographic angle different from that indicated by the exposure angle indicator. Additionally, non-uniform exposure can increase the susceptibility of the tomographic unit to produce streaks and artifacts in the image.

b. <u>Regulation</u>: Closure of all motions should be complete, exhibiting no open gaps, no asymmetries. Overlap in general should not exceed 20 degrees. Single phase units may be displayed as a series of overlapping dots. If the density of the reproduced trajectory is measured with a densitometer, the maximum density variation should not be greater than 0.3 density units

c. <u>Equipment</u>:

(1) Lead aperture plate (6 x 6 inch plate, with 1/8 inch hole).

(2) Plexiglas attenuator block (6x6x3/4 inch).

d. <u>Procedure</u>:

(1) Place 8 x 10 inch cassette in tray and adjust field to 3x3 inch in the plane of the image receptor.

(2) With the x-ray tube perpendicular to the table or using the center positioning light on the unit, position the lead aperture plate on top of the 5 cm thick Plexiglas spacer and position on the tabletop so the hole in the plate is coincident with the central ray of the x-ray field.

(3) Select the most commonly used tomographic motion, exposure angle and sweep speed. Set indicated cut level to 12 cm.

(4) Set technique of 60 kVp, and approximately 100 mAs. The technique may have to be altered to attain an image that has a density in the range of 1.0 to 1.5 in the area of the aperture image.

(5) Make an exposure, return to vertical and make 1 additional exposure and process the film

(6) Repeat above for each clinically used tomographic motion, exposure angle and sweep speed.

e. <u>Interpretation Of Results</u>:

(1) The tomographic image of the hole in the aperture place is a radiographic reproduction of the trajectory of the x-ray tube during the tomographic exposure. When the test images are viewed, the density of the image over the reproduced trajectory should appear uniform. Variations of the uniformity of the image density are indicative of mechanical problems in the tomographic drive mechanism.

(2) The images should also be evaluated to determine stability of tube motion i.e. the pattern reproduced on a linear system should be uniform in density and describe as a straight line, not a wobbly one and should be of equal length each side of center.

6. *Tomographic Resolution*

a. Purpose: Clarity of anatomical information is critically dependent upon the spatial resolution provided by the tomographic unit.

b. Regulation: Most tomographic units should be able to visualize 30 to 40 mesh wire.

c. Equipment:

(1) Tomographic resolution test object embedded in acrylic.

(2) Two 6x6x2 inch Plexiglas attenuator blocks.

e. Procedure:

(1) Select tomographic motion, sweep speed and exposure angle used most commonly for clinical imaging. Select a cut level of 10.5 cm.

(2) Position the two 5 cm (2 inch) thick spacer blocks, with the resolution test object on top of the two blocks, on the tabletop and center with respect to the tomographic field. For linear systems, orient the resolution test object so that the slope of the wire mesh patterns is perpendicular to the direction of the tube travel.

(3) Select technique of 60 kVp and approximately 20 mAs.

(4) Insert 8 x 10 inch cassette to the cassette tray. Collimate the field to the cassette dimensions.

(5) Expose and process the film.

(6) Repeat above for each clinically used tomographic motion, sweep speeds and exposure angles.

f. Interpretation Of Results:

(1) View each film on a radiographic illuminator. Determine the finest mesh which is just resolved. The mesh will be in best focus at the level of the cut plane. The mesh patterns are: 20, 30, 40 and 50 mesh holes per inch.

7. *Representative Entrance Skin Exposures*

See chapter 15 and appendix I.

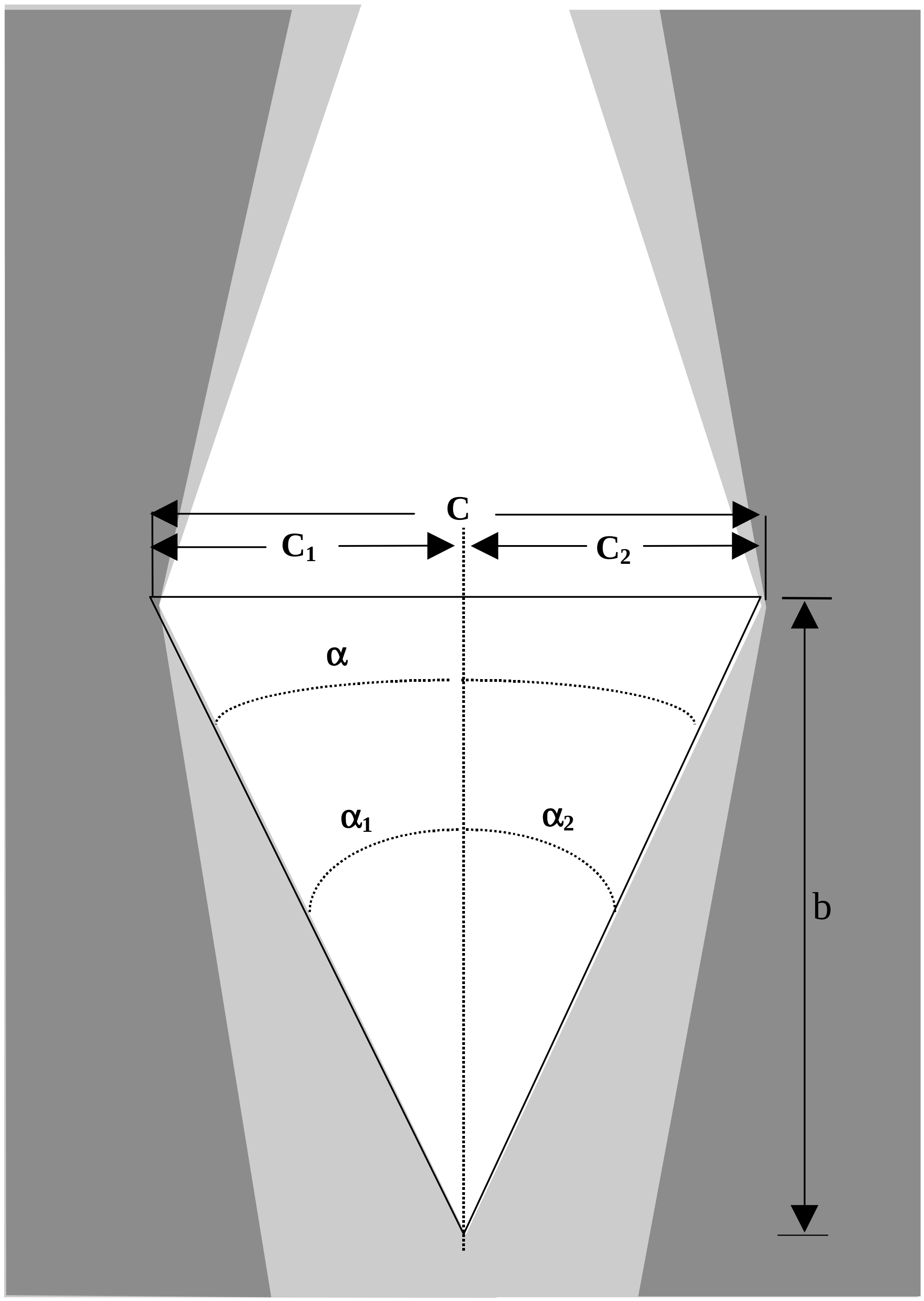
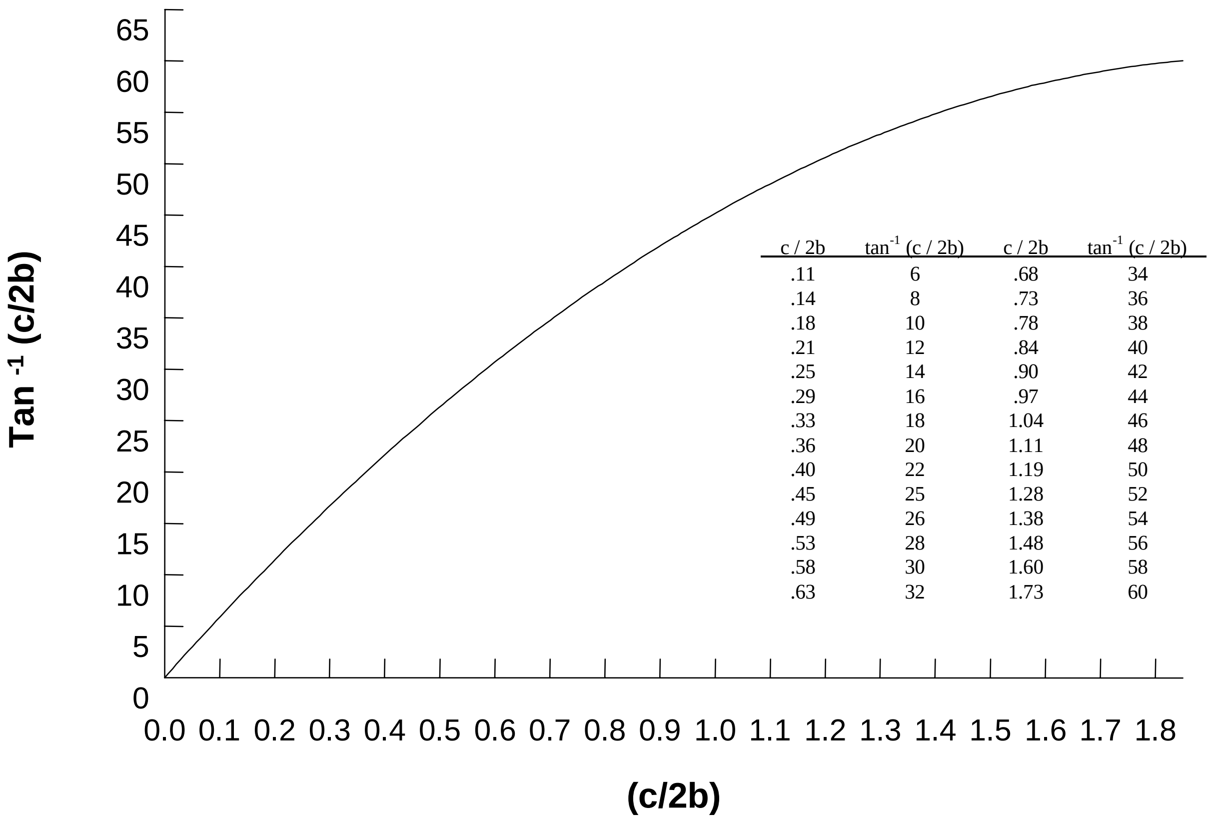


Figure E-1. Tomographic angle (test film image). Required measurements are shown.



c / 2b	$\tan^{-1}$ (c / 2b)	c / 2b	$\tan^{-1}$ (c / 2b)
.11	6	.68	34
.14	8	.73	36
.18	10	.78	38
.21	12	.84	40
.25	14	.90	42
.29	16	.97	44
.33	18	1.04	46
.36	20	1.11	48
.40	22	1.19	50
.45	25	1.28	52
.49	26	1.38	54
.53	28	1.48	56
.58	30	1.60	58
.63	32	1.73	60

Figure E-2. Relationship between the quantity (c / 2b) and $\tan^{-1}$ (c / 2b) used to determine the tomographic exposure angle α and tomographic exposure angles α_1 and α_2. To use this graph, calculate the value of the quantity (c / 2b) and find its position along the x-axis. Then extrapolate from that value to determine the $\tan^{-1}$ (c / 2b) value along the y-axis.

Tomographic Equipment Data Forms

Tomographic Cut Level Indicator Accuracy

Date:_______________ Room No:_______________

Equipment Identification:____

Type of Tomographic Motion:________________

Exposure Angle:_______________Sweep Speed:_______________

Technique Factors:________________kVp_______________mA______________time

Indicated Cut Level (centimeters)	1	3	5	7
Measured Cut Level (centimeters)				
Cut Level Indicator Accuracy (Indicated-Measured) (± 5 mm)				

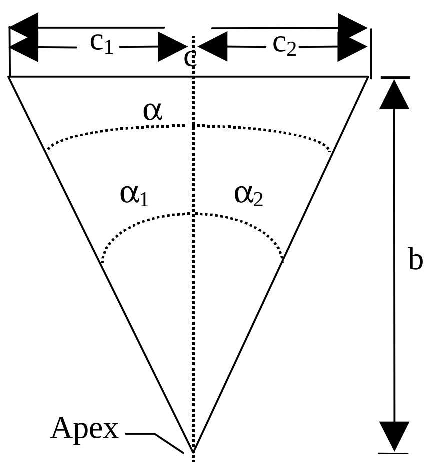
Tomographic Exposure Angle

b:_____________c:_____________c_1:_____________c_2:_____________

α:_____________^{o} α_1:______________^{o} α_2:______________^{o}

Exposure Angle Accuracy (Indicated angle - Measured angle): _____________^{o}

Symmetry of Exposure Angle ($\alpha_1 - \alpha_2$): _____________^{o}



Reconstruction of Tomographic Test Image:

b: Measured from image of tomographic test tool scale (distance from apex to base of reconstructed triangle)

c: Measured with centimeter ruler on test film

$\alpha = 2 \tan^{-1} (c/2b)$

$\alpha_1 = 2 \tan^{-1} (c_1/2b)$

$\alpha_2 = 2 \tan^{-1} (c_2/2b)$

Tomographic Cut Thickness

Exposure Angle:________________Sweep Speed:________________

Technique Factors:_________________kVp_________________mA_______________time

Indicated Cut Level:__________________________

Measured Cut Level:__________________________

Thickness Tomographic Plane_________________

Flatness of Tomographic Plane

Exposure Angle:________________Sweep Speed:________________

Technique Factors:_________________kVp_________________mA_______________time

Indicated Cut Level:__________________________

Measured Cut Level: Quadrant 1:_________________

Quadrant 2:_________________

Quadrant 3:_________________

Quadrant 4:_________________

Center: __________________

Maximum Variation in Level of Cut Plane:______________

Uniformity of Tomographic Exposure

Exposure Angle:_______________Sweep Speed:_______________

Technique Factors:________________kVp________________mA______________time

Height of Test Aperture Above Table:

Cut Level Used for Test: _______________cm

Uniformity of Exposure Over Trajectory Image: _______________cm

Stability of Motion Over Trajevtory Image: _________________

Completeness of Closure In Trajectory Image: _________________

Degree of Overlap In Trajectory Image: _________________

Tomographic Resolution

Exposure Angle:_______________Sweep Speed:_______________

Technique Factors:________________kVp________________mA______________time

Nominal Focal Spot Size Used: _______________mm

Cassette/Screen/Film Used: _______________

Height of Resolution Mesh Above Table: _______________cm

Indicated Cut Level: _______________cm

Number of Finest Mesh Resolved in Test Image: _______________mesh

Remarks/Comments:

Appendix F

Performance Tests for Computerized Tomographic Units

A. General Requirements for Computed Tomography Equipment

1. *Table Loading*

a. Purpose: To verify manufacturer's weight loading specifications for the patient support device.

b. Regulations: Refer to manufacturer's specifications.

c. Equipment: Weights and/or persons totaling the manufacturer's loading specifications.

d. Procedure: Distribute specified weight over table top in proportion to normal weight distribution. Check full range of vertical and horizontal motion. Record maximum weight and range of motion. Do not load table beyond manufacturer's specification.

e. Interpretation of results: If table loading requirements do not meet manufacturer's specifications consult a qualified service engineer.

2. *Laser Light Alignment*

a. Purpose: To ensure that laser lights are properly aligned with the scan slice

b. Regulations: Manufacturer's specification or $\pm$ 2 mm.

c. Equipment: Ready pack film, pin/needle, and ruler.

d. Procedure:

(1) Align the edges of a prepackaged film sheet to the edges of the acrylic backing plate. Secure with tape.

(2) Secure film/plate with tape to table top along long axis of table and raise table to head position. If both internal and external alignment lights are provided, position plate so that both lights are visible on film surface if possible.

(3) Turn on internal alignment light and mark light location on film by piercing film pack with pin at several points along the illuminated line. Repeat for the external light, using a different pinhole pattern to allow later identification of the two lasers.

(4) Expose film at inner light location, using narrowest slice setting with standard head technique. For external light, move table to scan position under software control and repeat scan.

e. Interpretation of results:

(1) After processing films, recreate the laser lines using the localization light hole indicators on the film.

(2) Measure the separation between the lines drawn from the holes in the processed film to the middle of the radiation slices.

(3) In the absence of manufacturer's specifications, the error should not exceed $\pm$ 2 mm.

3. *Table Positioning*

a. Purpose: To ensure that table movement and localization is accurate.

b. Regulations: Manufacturer's specifications or $\pm$ 1 mm.

c. Equipment: Ruler.

d. Procedure: Tape a ruler to the fixed portion of the patient support assembly. Make a mark on the table adjacent to the tape measure. Move the table both in and out of the gantry to predetermined distances. Record the actual and selected distances traveled (typically 1, 10 and 40 cm.).

e. Interpretation of results: The table should move smoothly and accurately to within 1 mm of target in either movement direction. Consult a qualified engineer if the requirement is not met.

4. *Table Incrementation*

a. Purpose: To ensure that table incrementation is accurate.

b. Regulations: Manufacturer's specifications or $\pm$ 1 mm.

c. Equipment: AAPM or CTDI phantom, ready pack film and ruler.

d. Procedure:

(1) Attach a piece of ready pack film to the phantom. Place the phantom on the patient support assembly. Expose the film using a 5 slice set of 5 mm thick slices on 5 mm centers.

(2) Develop the film and measure the distance between the centers of each set of adjacent density bands.

e. Interpretation of Results: The average distance measured between adjacent density band centers should equal the interslice movement $\pm$ 1 mm. If they are not consult a qualified service engineer.

5. *Table/Gantry Alignment*

a. Purpose: To ensure proper alignment of the table and gantry isocenter.

b. Regulations: Manufacturer's specifications or $\pm$5 mm.

c. Equipment: Ruler.

d. Procedure:

(1) Using the laser light, raise the scanning table until the lateral lasers intersect the horizontal plane.

(2) Insert the table into the gantry opening.

(3) Scan the table using the standard head technique. Using the electronic ruler and grid, project the distance from grid center to right and left table edges onto the grid.

(4) Compare the two distances and determine the difference between them.

(5) Calculate misalignment as half the difference between the two measurements.

e. Interpretation of Results: Misalignment of the two table edges and isocenter should be $\leq$ 5 mm. If it is not consult a qualified service engineer.

6. *Gantry Tilt Angle*

a. Purpose: To ensure the gantry tilt angle is within $\pm$ 3 degrees of the nominal setting.

b. Regulations: Gantry tilt angle should be within $\pm$ 3 degrees of the nominal setting.

c. Equipment: Ready pack film (optional) and protractor.

d. Procedure: This test may be conducted either by a mechanical method or using radiation.

(1) Mechanical method: Place a protractor on the front face of the scanner. Note the angle of the protractor. Tilt the gantry to predetermined forward and backward angles. (extreme forward, extreme backward and zero). At each gantry stop, record the measured vs. indicated gantry angle.

(2) Radiation method: Place a piece of ready pack film placed along the sagittal plane, perpendicular to the scan plane. Make an exposure using a 1 mm slice thickness (or smallest available) at each gantry stop. Develop the film. Measure and record the actual gantry angles.

e. Interpretation of Results: The gantry tilt angles determined by either the mechanical or radiation method must be within ± 3 degrees of the nominal setting. If not consult a qualified service engineer.

7. *Exposure Slice Width*

a. Purpose: To ensure that the exposure slice width is accurate.

b. Regulations: The exposure slice width should be within ± 1 mm of the nominal slice width setting.

c. Equipment: Phantom, ready pack film and ruler.

d. Procedure:

(1) Place a phantom (AAPM or CTDI) on the patient support assembly. Attach a piece of ready pack film to the phantom. Run a series of CT slices. Increment table and repeat for other slice widths.

(2) Develop the film. Measure and record the distance from the leading edge to the outside edge of the set of contiguous slices. Divide by the number of slices in the set. Record this value as the average slice width. The smallest slice width should be carefully evaluated. (i.e., a table incrementation of 1 mm with a 1 mm slice width may cause the slices to overlap since most 1 mm slices are actually closer to 1.5 mm). If this occurs repeat scan with a larger table spacing.

e. Interpretation of Results: The exposure slice width should be within + 1 mm of the nominal setting. In general, slice width is not adjustable. Further evaluation of slice width will be conducted with a phantom and is explained in the slice sensitivity section. A service engineer should be consulted if both evaluations indicate the slice width is not within ± 1 mm or manufacturer's specifications.

8. *Projection to Scan Accuracy and Artifact*

a. Purpose: To evaluate projection to scan accuracy and artifacts.

b. Regulations: Projected image should be within ± 1 mm of scan location. There should be no "star" artifact present.

c. Equipment: Metal marker such as radiopaque BB.

d. Procedure:

(1) Place a phantom on the patient support assembly. Place a radiopaque marker on the phantom. Position the assembly to scan the marker.

(2) Scan the phantom with a sagittal axis scan centered on the marker. Then scan the phantom with an axial scan centered on the marker using the smallest available slice width.

(3) Review the sagittal scan. Measure and record the distance between the marker and the "0.0" on the display. Review the axial scan to ensure that the marker is present. (If not adjust the table and rescan). Record whether a "star" artifact is present.

e. Interpretation of Results:

(1) The marker should be within ± 1 mm in the projected image. A combination of laser light misalignment and projection to scan misalignment may result in unsatisfactory scanner performance. A qualified service engineer should be consulted to correct the misalignment.

(2) A distinct "star" artifact should not be present when using the radiopaque skin markers. This would result in poor image quality for any patient that required their use. (A small artifact will most likely be present). Consult a qualified service engineer if the artifact interferes with clinical image quality.

9. *Image Noise*

a. Purpose: To ensure that an image of a phantom filled with a uniformly attenuating material shows minimal noise over the field of view.

b. Regulations:

(1) In the absence of manufacturer's noise specifications see section e. below.

c. Equipment: Uniform water phantom. Prepare phantom as follows:

(1) Ensure all water phantom inserts to be used are placed in the water phantom before filling.

(2) Prior to use, the water phantom should be nearly filled with deionized water, following manufacturer's instructions.

(3) Trapped air bubbles should be dispelled by mechanical agitation.

(4) The water filled phantom should be allowed to "settle" overnight.

(5) After a settling period, the phantom should be filled completely and all remaining air displaced.

d. Procedure:

(1) Perform calibration scan according to manufacturer's recommendations. This can be performed by the service engineer prior to physicist's evaluation.

(2) Center water phantom in the gantry opening using phantom brackets if available. Align a section of phantom without inserts or test tools (just water) for scanning (or use manufacturer's noise/uniformity phantom).

(3) Scan phantom using the desired parameters. Save the image. Repeat using other FOVs and reconstruction algorithms, as necessary.

(4) Using the statistics tools, create a circular ROI of approximately 100 mm^2. Measure the mean pixel and standard deviation values for ROIs placed at the image center and at 3, 6, 9 and 12 o'clock positions at 70% of the radius.

e. Interpretation of Results: In the absence of manufacturer's specifications, noise (standard deviation) should be < 4 CT numbers in standard head and body modes and < 35 CT numbers in the high resolution mode. Consult a qualified service engineer if noise is not within these specifications. Excessive noise will effect low contrast image quality.

10. *Field Uniformity*

a. Purpose: To ensure that an image of a phantom filled with a uniformly attenuating material shows adequate signal uniformity over the field of view.

b. Regulations: Manufacturer's specifications or section e. below. (AAPM specification is 5 CT numbers).

c. Equipment: Uniform water phantom.

d. Procedure: Utilize the previously recorded average CT numbers for each ROI for each scan mode.

e. Interpretation of Results: In the absence of manufacturer's specifications, uniformity (i.e., maximum variation between the mean CT numbers for any two ROIs in a single study slice) should not exceed 5 CT numbers, preferably within 2 CT numbers. If uniformity is not within specifications contact a qualified service engineer.

11. *CT Number Calibration*

a. Purpose: To ensure that the CT numbers associated with air and water are accurate..

b. Regulations: In the absence of manufacturer's specifications the water ROI should be 0 $\pm$ 1.5 HU and the air ROI should be 1000 $\pm$ 3 HU in standard clinical mode. For other modes the ROI should be $\pm$ 3 HU.

c. Equipment: Water phantom (head and/or body) and previously scanned data from noise images.

d. Procedure: Utilize the previously recorded average CT numbers for the center ROI and air ROI for each scan mode.

e. Interpretation of Results: If the CT number does not meet specification contact a qualified service engineer for adjustment.

12. *Linearity*

a. Purpose: To ensure CT number linearity for materials with a range of linear attenuation coefficients.

b. Regulations: Manufacturer's specifications or section e. below lists AAPM recommendations.

c. Equipment: Performance phantom linearity insert.

d. Procedure:

(1) Center the phantom with the linearity test tool in the gantry opening and align with the table. Move the section of the phantom with the test object to the scan plane.

(2) Scan the insert. Using the ROI function, determine the mean CT number of each pin and the water background. Save the annotated image.

e. Interpretation of Results:

(1) Plot the mean CT numbers for each material as a function of its linear attenuation value.

(2) Note that the linear attenuation values are dependent on the effective energy of the beam (should be determined during acceptance).

(3) In the absence of manufacturer's specifications, the AAPM recommends "that any CT number mean value should not deviate by more than two times the standard deviation from a best fit straight line describing the relationship of CT number mean values to linear attenuation coefficient over the ranger of polyethylene to Plexiglas.

13. *Contrast Scale*

a. Purpose: To ensure contrast scale of CT numbers.

b. Regulations: Manufacturer's specifications or section e. below lists AAPM recommendations.

c. Equipment: Performance phantom uniform water section.

d. Procedure:

(1) Center the phantom with the water section in the gantry opening and align with the table. Move the water section of the phantom to the scan plane.

(2) Scan the insert. Using the ROI function, determine the mean CT number of air outside the phantom and the water section. Save the annotated image.

e. Interpretation of Results:

(1) Plot the mean CT numbers for the water and the air as a function of its linear attenuation value.

(2) Follow manufacture specifications and track over time.

14. *Low Contrast Sensitivity*

a. Purpose: To ensure appropriate image contrast sensitivity.

b. Regulations: Manufacturer's specifications or section e. below., it is recommended that:

c. Equipment: Performance phantom with low contrast insert. High contrast resolution test tool is not appropriate for this test.

d. Procedure:

(1) Center phantom with contrast sensitivity insert in the gantry opening and align with the table. Move section of phantom with test object to scan plane.

(2) Scan using standard head algorithm and save the image.

(3) Using the ROI function, determine the mean CT numbers for the phantom and water background. Determine the percentage contrast using the formula:

$$\frac{|\ \text{CT \# background} - \text{CT\# phantom}\ |}{10}$$

(4) Determine the smallest array pattern visible with the naked eye. Adjust window, level and room light for best viewing.

(5) Repeat steps (2) through (4) using other algorithms, as desired.

e. Interpretation of Results:

(1) Results depend on both intrinsic contrast levels and display window and level settings. Image contrast depends on sensitivity profile width (slice thickness). Therefore, contrast comparisons among algorithms should be made using the same slice width.

(2) Refer to manufacturer's specifications, if available. In the absence of manufacturer's specifications, scanners should be able to detect:

(a) Using standard algorithm, 2.5 mm hole at 1.0 percent contrast, 3 mm hole at 0.6 percent contrast, and 6 mm hole at 0.35 percent contrast.

(b) Using low contrast mode, 2 mm at 1%, 2.8 mm at 0.6% and 4 mm holes at 0.35%.

(c) In high contrast mode, 4 mm at 1%, 8 mm at 0.6% and 13 mm holes at 0.35%.

15. *High Contrast Resolution*

a. Purpose: To ensure adequate image resolution.

b. Regulations: In the absence of manufacturer's specifications or section e. below.

c. Equipment: Performance phantom resolution insert.

d. Procedure:

(1) Center phantom with resolution insert in the gantry opening and align the table. Move section of phantom with resolution test object to scan plane.

(2) Scan test object using standard head and body algorithms, using an 8 to 10 mm slice width. Save images for analysis.

(3) Use the zoom function to magnify the test pattern. Determine the smallest array pattern or line pair visible using a minimal window and level resulting in optimal viewing.

(4) To evaluate resolution enhancement algorithms, repeat steps (1) through (3) using the appropriate algorithm, FOV, etc.

e. Interpretation of Results:

(1) Determine the smallest resolved test object using each scan protocol.

(2) Refer to manufacturer's specifications. In the absence of specifications from the manufacturer, the standard mode should minimally resolve the 1.0 mm test tool or 5 lp/cm while the 0.5 mm test object or 10 lp/cm should be resolved in higher resolution modes.

16. *Modulation Transfer Function*

a. Purpose: To ensure that the modulation transfer function (MTF) for all algorithms is established during acceptance testing procedures.

b. Regulations: The 10% and 50% MTF should be evaluated and documented for all algorithms. Refer to manufacturer's specifications for these values.

c. Equipment: Phantom containing high resolution wire and previous scans containing high resolution insert.

d. Procedure:

(1) Utilizing previous scans of the high resolution insert and the pixel plot function, display and print/record the pixel plot of the high resolution wire.

(2) Repeat for all scan modes.

e. Interpretation of Results:

(1) Utilizing a MTF program evaluate the pixel plots of each algorithm. Some CT scanners provide MTF evaluation software. If it is not provided contact the Department of Radiology at USUHS in Bethesda, MD for software.

(2) Since MTF evaluation is primarily conducted during acceptance testing procedures the manufacturer should be contacted immediately if manufacturer specifications are not met.

17. *Slice Sensitivity*

a. Purpose: To verify that the actual width of the imaged slice meets the manufacturer's specifications.

b. Regulations: Manufacturer's specifications or section e. below.

c. Equipment: Performance phantom sensitivity profile insert.

d. Procedure:

(1) Center the phantom with sensitivity profile test tool in the gantry opening and align with the table. Move the section of phantom with slice thickness insert to the scan plane.

(2) Scan the insert using the standard head algorithm and a ten mm slice thickness. Save the image.

(3) Set window to minimum and determine the maximum pixel value on the center ramp using the level control. Set level control to half of the maximum CT pixel value. Utilizing the electronic ruler, measure the width of each ramp.

(4) Repeat steps 2 and 3 above while varying the slice thickness from a maximum to a minimally used clinical setting. Save all annotated images.

e. Interpretation of Results:

(1) Determine the sensitivity profile width for each ramp section at each slice thickness tested.

(2) Refer to manufacturer's specifications for evaluation. In the absence of specifications, the measured profile width should be within ± 10 percent or ± 1 mm at the nominal slice width.

18. *Slice Dose*

a. Purpose: The surface slice dose should be established during acceptance testing to ensure that manufacturer's specifications are not exceeded.

b. Regulations: Refer to manufacturer's specifications.

c. Equipment: Phantom and TLDs or ready pack film.

d. Procedure:

(1) Place TLDs or ready pack film on a phantom to collect radiation from the scanned slices. A series of contiguous slices and single slices (separated by sufficient distance to reduce scatter) should be evaluated.

e. Interpretation of Results:

(1) TLDs should be read and recorded. Film should be evaluated using a scanning densitometer and H&D curve developed for the specific scanner kVp and film developer used. The manufacturer should be contacted if the surface slice dose is greater than manufacturer's specifications.

19. *Scatter*

a. Purpose: To establish and maintain control of the scatter pattern created by the CT scanner.

b. Regulations: Refer to manufacturer's isodose area plot for interior room measurements. Exterior room measurements should be less than 100 mrem per year for the general public.

c. Equipment: CTDI body phantom and electrometer with large (180 sq cm) probe.

d. Procedure:

(1) Center the CTDI phantom in the gantry opening and width of table. Place the probe at the first position to be evaluated. Scan under highest technique clinically used (1 slice) for body mode with the largest slice thickness. Record the electrometer reading. Move the probe to the next location and repeat the procedure.

e. Interpretation of Results:

(1) Exterior walls should not exceed the general public dose limit of 100 mrem per year.

(2) If doses within the room are significantly greater than the expected isodose values provided by the manufacturer a service engineer should be contacted.

20. *Radiation Protection and Safety (under construction)*

21. *MSAD (formerly CTDI)*

a. Purpose: To determine the radiation dose to tissues under different CT scan conditions.

b. Regulations: Manufacturer's specifications or section e. below.

c. Equipment: CTDI phantoms (head and/or body) and electrometer with CT probe.

d. Procedure:

(1) Place head CTDI phantom (16 cm phantom) in the patient head holder. Align the phantom so that the center hole coincides with gantry isocenter (using electronic grid) and the slice plane coincides with the center of the ion chamber sensitive volume.

(2) Align holes so that a hole is upper most at the "12 o'clock" position (this should also place holes at the 3, 6 and 9 o'clock positions).

(3) Scan the phantom using a 10 mm slice width. Look at the image to see if phantom is aligned; realign phantom, if necessary. Tape or secure phantom when aligned.

(4) Place ion chamber in the center hole, aligning the center of the sensitive volume with the scan plane laser,

(5) Place electrometer in exposure mode. Using standard head protocol, measure integrated exposure.

(6) Move chamber to the 3, 6, 9, and 12 o'clock positions. Repeat the measurements for each position.

(7) Repeat step (4) through (6) using different slice widths, kVps and mAs settings as necessary.

(8) Repeat the entire procedure using the body phantom, standard abdominal protocol and abdominal protocol variations as necessary.

(9) During acceptance testing, the head phantom may be scanned using abdominal protocol variations in addition to conventional scans using the abdominal phantom. These data can be used as a baseline to compare subsequent MSAD measurements using the head phantom only.

e. Interpretation of Results:

(1) Separate surface and isocenter exposure measurements should be calculated to provide the best data base for later use in dose estimates.

(2) Calculate MSAD in acrylic from exposure using the relationship:

$$MSAD = E \times K \times L/T \times 0.78$$

where L = effective length of ion chamber
K = chamber energy correction factor (from calibration certificate)
E = temperature and pressure corrected exposure (R),
0.78 = Rad/R conversion factor (for acrylic).
T = nominal slice width (variable)

(3) CTDI is defined as:

$$CDTI = \frac{1}{nT} \int_{-7T}^{+7T} D(z)\,dz$$

where (n) is the number of slices per scan, T is the selected slice width, D(z) is the dose at point "z" on any line parallel to the rotational axis for a single scan. Quantitatively CTDI is the average dose over an interval of width "T" equal to the selected slice width, at a point (x,y) in the plane of the middle slice of a series of 14 scans.

(4) MSAD and CTDI are identical if the ion chamber active length used to measure MSAD is equal to 14 slice thicknesses and the interval between slices equals the slice width. When the scan increment differs from the slice width, MSAD and CTDI are related as:

$$MSAD = \frac{T}{Z} \times CTDI$$

where T = selected slice width
Z = interval between slices

The equation does not hold if Z=0 or if Z>>T.

With thicker slices, MSAD tends to underestimate CTDI;
with thinner slices, MSAD overestimates CTDI.

(5) Compare MSAD with manufacturer's CTDI specifications. In the absence of specifications, the AAPM recommends that MSAD should agree to within + 20% of the manufacturer's CTDI target value.

22. *Beam Quality*

a. Purpose: To establish and verify the half value layer at clinically used kVp settings.

b. Regulations: Refer to manufacturer's specifications.

c. Equipment: Electrometer with CT probe and at least 10 mm aluminum.

d. Procedure:

(1) Ensure that the CT tube has been fixed in one location, preferably the top. This may require service engineer assistance.

(2) Place probe at isocenter, scan using largest slice thickness. Record electrometer reading.

(3) Place 4 mm aluminum within beam with good geometry. Repeat scan and record electrometer reading.

(4) Repeat procedure increasing aluminum until half value layer is reached.

(5) Repeat initial measurement to ensure that techniques and geometry have not been altered during procedure.

(6) Repeat for other kVp settings.

e. Interpretation of Results:

(1) If half value layer significantly exceeds manufacturer's specifications a service engineer should be contacted immediately. Excessive HVLs will reduce CT tube life.

23. *Hard Copy Output Device (under construction)*

COMPUTED TOMOGRAPHY EQUIPMENT DATA FORMS

COMPUTED TOMOGRAPHY EQUIPMENT DATA
Revised 01/01 REPORT SYMBOL MED 6470-15

1. FACILITY IDENTIFICATION

a. FACILITY NAME	b. UIC	
c. MAILING ADDRESS	d. BUILDING	e. ROOM

2. STATUS OF THE EQUIPMENT (INDICATE IF EQUIPMENT IS IN USE OR THE REASON FOR NOT BEING IN USE).

☐ IN USE ☐ TO BE REPAIRED ☐ STORED IN GOOD WORKING CONDITION
☐ NOT IN USE ☐ CANNOT BE REPAIRED ☐ OTHER

3. X-RAY EQUIPMENT IDENTIFICATION

a. PLANT ACCOUNT NUMBER ☐
b. YEAR EQUIPMENT WAS MANUFACTURED ☐
c. INSTALLATION DATE OF EQUIPMENT ☐
d. X-RAY EQUIPMENT IS CERTIFIED: YES ____ NO ____

e. COMPONENT	f. MANUFACTURER	g. MODEL	h. SERIAL NUMBER
1) CONTROL CONSOLE			
2) CT TABLE			
3) X-RAY TUBE ASSEMBLY			
TUBE #1 HOUSING			
TUBE #1 INSERT			
TUBE #1 COLLIMATOR			

☐ CONTINUED ON SEPARTE SHEET

4. DOSIMETRY EQUIPMENT

A. Radiation Exposure Meter used:

a. TYPE	b. MODEL	c. SERIAL NUMBER	d. CALIBRATION DATE DATE:

B. Computed Tomography Dose Index (CDTI) Phantom used:

a. TYPE	b. MODEL	c. SERIAL NUMBER	

C. Other Imaging Phantom used:

a. TYPE	b. MODEL	c. SERIAL NUMBER	

D. Other Imaging Phantom used:

a. TYPE	b. MODEL	c. SERIAL NUMBER	

E. Film Densitometer used:

a. TYPE	b. MODEL	c. SERIAL NUMBER	d. CALIBRATION DATE DATE:

F. Light meter used:

a. TYPE	b. MODEL	c. SERIAL NUMBER	d. CALIBRATION DATE DATE:

G. Other meter used:

a. TYPE	b. MODEL	c. SERIAL NUMBER	d. CALIBRATION DATE DATE:

5. DATE OF LAST RADIATION PROTECTION SURVEY DATE: ☐ UNKNOWN	**6.THIS EQUIPMENT REPLACED EQUIPMENT WITH** PLANT ACCOUNT NUMBER. ☐ UNKNOWN

7. INSPECTED BY: TITLE:	**REVIEWED BY:**	**DATE:**

GENERAL REQUIREMENTS FOR COMPUTED TOMOGRAPHY EQUIPMENT
Revised 01/01

1. FACILITY IDENTIFICATION

a. FACILITY NAME	b. UIC	
c. MAILING ADDRESS	d. BUILDING	e. ROOM

2. OPERATING PROCEDURES

	YES	NO	COMMENTS
a. CT SYSTEM OPERATED BY TRAINED PERSONNEL.			None
b. QUALITY CONTROL PROCEDURES AND ALLOWED VARIATIONS AVAILABLE FOR PHANTOM AT CONTROL CONSOLE?			None
c. QUALITY CONTROL PERFORMED REGULARLY?			None
d. DATES OF LAST SPOT CHECK AND CALIBRATION AVAILABLE?			None
e. TECHNIQUE CHART AVAILABLE AT THE OPERATORS CONSOLE?			None

3. RADIATION SAFETY EQUIPMENT AND ACCESSORIES

	YES	NO	COMMENTS
a. APRONS: ADEQUATE NUMBER			None
GOOD CONDITION			
b. GLOVES: ADEQUATE NUMBER			None
GOOD CONDITION			
c. GONADAL SHIELDS TYPE: Leaded Rubber Shield			None
d. ADEQUATE PATIENT IMMOBILIZATION EQUIPMENT			None
e. WARNING LABLELS PRESENT AT CONTROL PANEL (CERTIFIED EQUIPMENT REQUIREMENT)			None
f. LIGHTS, METERS IN GOOD WORKING CONDITION.			None
g. INTERLOCKS ARE SATISFACTORY.			None
h. MECHANICAL/ELECTRICAL STOPS IN GOOD CONDITION			
i. CABLES AND GROUPING IN GOOD CONDITION.			None

4. GENERAL CHARACTERISTICS AND PERFORMANCE REQUIREMENTS.

	YES	NO	COMMENTS
a. BEAM ON INDICATORS			
CONTROL AND GANTRY HAVE VISUAL INDICATORS FOR EXPOSURE?			None
EMERGENCY SWITCH LAVELED AND ACCESSIBLE?			None
b. INDICATION OF CT CONDITIONS OF OPERATION:			
CT CONDITIONS INDICATED PRIOR TO SCAN?			None
CT CONDITIONS INDICATED DURING SCAN?			None
c. TERMINATED OF EXPOSURE:			
AUTOMATIC TERMINATION OCCURS < 110% OF PRESET VALUE?			None
VISIBLE SIGNAL INDICATES EXPOSURE TERMINATION?			None
OPERATOR CAN TERMINATE EXPOSURE?			None

GENERAL REQUIREMENTS FOR COMPUTED TOMOGRAPHY EQUIPMENT

4. GENERAL CHARACTERISTICS AND PERFORMANCE REQUIREMENTS. (CONTINUED)

	YES	NO	COMMENTS
d. TOMOGRAPHIC PLANE INDICATION AND ALIGNMENT:			
VISUAL DETERMINATION OF TOMOGRAPHIC PLANE POSSIBLE?			None
TOTAL ERROR IN INDICATED TOMOGRAPHIC PLANE < 5 MM?			None
LIGHT VISUAL INDICATORS PERMIT VISUALIZATION IN AMBIENT LIGHT OF 500 LUX?			None
e. MAXIMUM SURFACE CTDI IDENTIFICATION:			
LOCATION: TOWARD CEILING FROM ISOCENTER?			None
f. FACILITY DESIGN REQUIREMENTS:			
ORAL COMMUNICATION (CONTROL AREA TO PATIENT) IS TWO WAY?			No
TECHNOLOGIST HAS CONTINUOUS OBSERVATION OF PATIENT?			No

5. TABLE, GANTRY, AND LASER LIGHT GENERAL CHARACTERISTICS AND PERFORMANCE REQUIREMENTS.

a. TABLE LOADING (Required at acceptance test and replacement of table.)

loaded maximum height (mm) ______ loaded minimum height (mm) ______

b. LASER LIGHT ALIGNMENT (Required at acceptance test and replacement of laser equipment.)

Difference between radiation slice and internal laser light (mm) ______

Difference between radiation slice and external laser light (mm) ______

c. TABLE POSITIONING (Required at acceptance test and replacement of table.)

Difference between initial location and final location (mm) ______

d. TABLE INCREMENTATION (Required at periodic and acceptance test.)

Distance between centers of adjacent density bands of set of 5 mm thick slices (mm)	
Difference between actual and indicated table movement of: 100 mm increment (mm)	
200 mm increment (mm)	
300 mm increment (mm)	
400 mm increment (mm)	
500 mm increment (mm)	
600 mm increment (mm)	

e. TABLE AND GANTRY ALIGNMENT (Required at acceptance test and replacement of associated equipment.)

Difference between table and gantry isocenter (mm) ______

f. GANTRY TILT ANGLE (Required at acceptance test and replacement of associated equipment.)

Difference between extreme left postition (______degree) and measured (degrees)	
Difference between extreme right position (______degree) and measured (degrees)	
Difference between zero position (______degree) and measured (degrees)	

g. EXPOSURE SLICE WIDTH (Required periodic and acceptance test.)

Difference between actual and indicated slice width for various slice thicknesses.

Technique used: ____________mA, ____________sec, _____________kVp

Single Slice			Multi Slice (set of 5 contiguous)		
Indicated (mm)	Actual (mm)	Difference (mm)	Indicated (mm)	Actual (mm)	Ratio (mm)

GENERAL REQUIREMENTS FOR COMPUTED TOMOGRAPHY EQUIPMENT

5. TABLE, GANTRY, AND LASER LIGHT GENERAL CHARACTERISTICS AND PERFORMANCE REQUIREMENTS. (CONTINUED)

h. PROJECTION SCAN ACCURACY (Required at periodic and acceptance test.)

Difference between radiopaque marker and display location (mm) ______

6. SLICE DOSE BY FILM DOSIMETRY (Recommended at acceptance test)

Single slice dose (rad)	
Multislice dose (rad)	

7. ROOM SURVEY FOR RADIATION SCATTER Required at periodic and acceptance test.)

Technique used: ___________mA, ______________sec, _____________kVp, _____________slice thickness

Phantom used: ________________________

Radiation meter used: ____

Location	Exposure Measured (mR/hr)	mR/scan
1 meter from isocenter		
base of table		
patient left side of gantry		
patient right side of gantry		
2 meters from isocenter		
end of table		
tech door opening		
console		
hallway door opening		
hallway (south side)		
hallway (north side)		
hallway (east side)		
hallway (west side)		

8. BEAM QUALITY - HVL (Required at acceptance test or x-ray tube replacement.)

Technique used: ___________mA, ______________sec, _____________kVp, _____________slice thickness

Radiation meter used: ____

Added Filtration (mm)	Output (mR)

Calculated HVL (mm Al) ______

9. BEAM QUALITY - KVP (Required at acceptance test or x-ray tube replacement.)

Technique used: ___________mA, ______________sec, _____________kVp, _____________slice thickness

Meter used: ____

Indicated kVp	Measured kVp	% Error

GENERAL REQUIREMENTS FOR COMPUTED TOMOGRAPHY EQUIPMENT

10. DISPLAY EVALUATION (Required at periodic and acceptance test.)

SMPTE LOCATION	Optical Density	Illuminance (cd/m^3)
0%		
10%		
40%		
90%		
100%		

11. COMMENTS

MULTI SCAN AVERAGE DOSE (MSAD) (formerly CTDI**) AND OUTPUT LINEARITY/REPRODUCIBILITY EVALUATION**
Revised 01/01

MSAD EQUATION AND VARIABLE DEFINITIONS

Measurements are in dose (RAD) to acrylic, in Rad/100 mAs and are normalized relative to isocenter.

MSAD = (E x K x L x f)/T

where:
E = exposure reading (R/scan)
K = chamber energy correction factor
L = length of ion chamber
f = dose/exposure factor for acrylic
T= nominal slice thickness

K	
L	
f	

1. HEAD MEASUREMENTS (Required at periodic and acceptance test.)

Technique used: ________mA, _________sec, __________kVp, ________scan FOV, __________scan mode

Indicated mAs ___________

Slice Thickness (mm) [ ]

Location of Chamber (degree)	E (R/scan)	Manufacturer recommended values (rad)	MSAD (rad)	rad/100 mAs	Normalized to Isocenter

Slice Thickness (mm) [ ]

Location of Chamber (degree)	E (R/scan)	Manufacturer recommended values (rad)	MSAD (rad)	rad/100 mAs	Normalized to Isocenter

Slice Thickness (mm) [ ]

Location of Chamber (degree)	E (R/scan)	Manufacturer recommended values (rad)	MSAD (rad)	rad/100 mAs	Normalized to Isocenter

Slice Thickness (mm) [ ]

Location of Chamber (degree)	E (R/scan)	Manufacturer recommended values (rad)	MSAD (rad)	rad/100 mAs	Normalized to Isocenter

MULTI SCAN AVERAGE DOSE (MSAD) (formerly CTDI**) AND OUTPUT LINEARITY/REPRODUCIBILITY EVALUATION**

2. BODY MEASUREMENTS (Required at periodic and acceptance test.)

Technique used: ________mA, _________sec, __________kVp, ________scan FOV, __________scan mode

Indicated mAs ___________

Slice Thickness (mm) [ ]

Location of Chamber (degree)	E (R/scan)	Manufacturer recommended values (rad)	MSAD (rad)	rad/100 mAs	Normalized to Isocenter

Slice Thickness (mm) [ ]

Location of Chamber (degree)	E (R/scan)	Manufacturer recommended values (rad)	MSAD (rad)	rad/100 mAs	Normalized to Isocenter

Slice Thickness (mm) [ ]

Location of Chamber (degree)	E (R/scan)	Manufacturer recommended values (rad)	MSAD (rad)	rad/100 mAs	Normalized to Isocenter

Slice Thickness (mm) [ ]

Location of Chamber (degree)	E (R/scan)	Manufacturer recommended values (rad)	MSAD (rad)	rad/100 mAs	Normalized to Isocenter

MULTI SCAN AVERAGE DOSE (MSAD) (formerly CTDI**) AND OUTPUT LINEARITY/REPRODUCIBILITY EVALUATION**

3. OUTPUT REPRODUCIBILITY MEASUREMENTS (Required at periodic and acceptance test.)

Processing Algorithm used: __________ Probe located at __________ of _________ phantom

Slice thickness ____________mm

kVp	mA	time (sec)	mR/scan	mR/mAs
80				
120				
140				

4. OUTPUT REPRODUCIBILITY MEASUREMENTS (Required by periodic and acceptance test.)

Processing Algorithm used: __________ Probe located at __________ of _________ phantom

Slice thickness ____________mm

	Indicated					Measured	
kVp	mA	time (sec)	filter	FS size	kV	time (sec)	R

5. COMMENTS

WATER PHANTOM PERFORMANCE EVALUATION
Revised 01/01

1. CT NUMBER CALIBRATION (Required at periodic and acceptance test.)

Technique used: ________ mA
________ sec
________ kVp
________ slice thickness

Processing Algorithm used: ______________

scan FOV ________ cm

ROI Site	CT Number (HU)
Air	
water	

ROI size [ ]

Is CT Number for Air -1000 +/- 3 HU Y / N
Is CT Number for water 0 +/- 3 HU Y / N

2. CONTRAST SCALE (Required at periodic and acceptance test.)

Technique used: ________ mA
________ sec
________ kVp
________ slice thickness

Processing Algorithm used: ______________

scan FOV ________ cm

ROI Site	CT Number (HU)
Air	
water	

ROI size [ ]

Contrast Scale (cm^{-1}/CT Number) [ ]

3. COMMENTS

AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE (AAPM) PERFORMANCE EVALUATION
Revised 01/01

1. NOISE EVALUATION (Required at periodic and acceptance test.)

A.

Technique used: ________ mA
________ sec
________ kVp
________ slice thickness
Processing Algorithm used: ______________
scan FOV ________ cm
ROI Size ________ mm2

ROI Site	Mean (HU)	Standard Deviation
isocenter		
0 degree		
90 degree		
180 degree		
270 degree		

Average HU	Average SD

Maximum Deviation	Maximum Deviation (%)

B.

Technique used: ________ mA
________ sec
________ kVp
________ slice thickness
Processing Algorithm used: ______________
scan FOV ________ cm
ROI Size ________ mm2

ROI Site	Mean (HU)	Standard Deviation
isocenter		
0 degree		
90 degree		
180 degree		
270 degree		

Average HU	Average SD

Maximum Deviation	Maximum Deviation (%)

C.

Technique used: ________ mA
________ sec
________ kVp
________ slice thickness
Processing Algorithm used: ______________
scan FOV ________ cm
ROI Size ________ mm2

ROI Site	Mean (HU)	Standard Deviation
isocenter		
0 degree		
90 degree		
180 degree		
270 degree		

Average HU	Average SD

Maximum Deviation	Maximum Deviation (%)

D.

Technique used: ________ mA
________ sec
________ kVp
________ slice thickness
Processing Algorithm used: ______________
scan FOV ________ cm
ROI Size ________ mm2

ROI Site	Mean (HU)	Standard Deviation
isocenter		
0 degree		
90 degree		
180 degree		
270 degree		

Average HU	Average SD

Maximum Deviation	Maximum Deviation (%)

2. UNIFORMITY EVALUATION (Required at periodic and acceptance test.)

Technique used: ________ mA
________ sec
________ kVp
________ slice thickness
Processing Algorithm used: ______________
scan FOV ________ cm
ROI Size ________ mm2

ROI Site	Mean (HU)
isocenter	
0 degree	
90 degree	
180 degree	
270 degree	

Average (HU)

Maximum Deviation

AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE (AAPM) PERFORMANCE EVALUATION

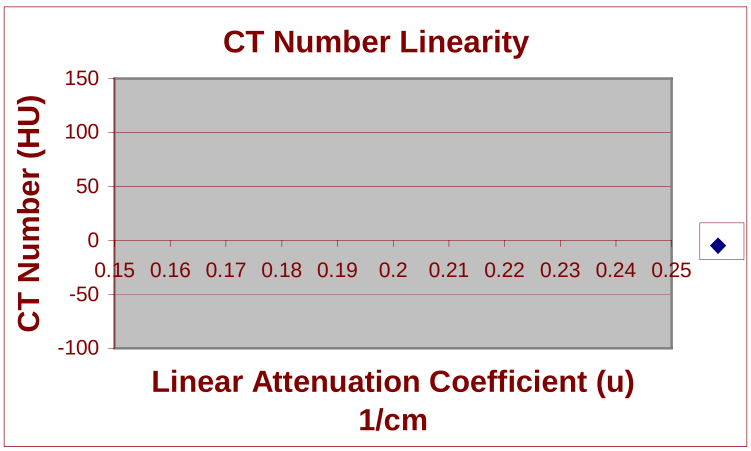
3. LINEARITY EVALUATION (Required at periodic and acceptance test.)

Technique used: ________ mA
________ sec
________ kVp
________ slice thickness

Processing Algorithm used: ________________

scan FOV ________ cm
ROI size ________ mm2

Material	Expected HU value	Measured HU value	Linear Attenuation Coefficient (µ) cm^{-1}
Polyethylene	-92		0.177
Plexiglass	120		
Polystyrene	-24		0.191
Polycarbonate	102		0.217
Nylon	92		0.216
Water	0		0.194



Correlation Coefficient ________

4. LOW CONTRAST SENSITIVITY (Required at periodic and acceptance test.)

A.

Technique used: ________ mA
________ sec
________ kVp
________ slice thickness

scan FOV ________ cm
ROI Size ________ mm2

Algorithm Used	Contrast (ROI 1)	Contrast (ROI 2)	Percent Contrast	Smallest Hole Resolved (mm)

B.

Technique used: ________ mA
________ sec
________ kVp
________ slice thickness

scan FOV ________ cm
ROI Size ________ mm2

Algorithm Used	Contrast (ROI 1)	Contrast (ROI 2)	Percent Contrast	Smallest Hole Resolved (mm)

AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE (AAPM) PERFORMANCE EVALUATION

5. HIGH CONTRAST RESOLUTION (Required at periodic and acceptance test.)

A.

Technique used: ________ mA
________ sec
________ kVp
________ slice thickness
scan FOV ________ cm

Algorithm Used	Smallest Hole Resolved (mm)

B.

Technique used: ________ mA
________ sec
________ kVp
________ slice thickness
scan FOV ________ cm

Algorithm Used	Smallest Hole Resolved (mm)

6. SLICE SENSITIVITY (Required at periodic and acceptance test.)

Technique used: ________ mA
________ sec
________ kVp
scan FOV ________ cm
Algorithm used ________________

Slice Thickness (mm)	Left	Center	Right	Within +/- 1mm of nominal thickness

7. COMMENTS

CATPHAN PERFORMANCE EVALUATION
Revised 01/01

1. PHANTOM POSITION VERIFICATION (Required at periodic and acceptance test.)

Is phantom correctly aligned? Y / N If no reposition phantom.

2. NOISE EVALUATION (Required at periodic and acceptance test.)

A.

Technique used: ________ mA
________ sec
________ kVp
________ slice thickness
Processing Algorithm used: ________________
scan FOV ________ cm
ROI Size ________ mm2

ROI Site	Mean (HU)	Standard Deviation
isocenter		
0 degree		
90 degree		
180 degree		
270 degree		

Average HU	Average SD

Maximum Deviation	Maximum Deviation (%)

B.

Technique used: ________ mA
________ sec
________ kVp
________ slice thickness
Processing Algorithm used: ________________
scan FOV ________ cm
ROI Size ________ mm2

ROI Site	Mean (HU)	Standard Deviation
isocenter		
0 degree		
90 degree		
180 degree		
270 degree		

Average HU	Average SD

Maximum Deviation	Maximum Deviation (%)

C.

Technique used: ________ mA
________ sec
________ kVp
________ slice thickness
Processing Algorithm used: ________________
scan FOV ________ cm
ROI Size ________ mm2

ROI Site	Mean (HU)	Standard Deviation
isocenter		
0 degree		
90 degree		
180 degree		
270 degree		

Average HU	Average SD

Maximum Deviation	Maximum Deviation (%)

D.

Technique used: ________ mA
________ sec
________ kVp
________ slice thickness
Processing Algorithm used: ________________
scan FOV ________ cm
ROI Size ________ mm2

ROI Site	Mean (HU)	Standard Deviation
isocenter		
0 degree		
90 degree		
180 degree		
270 degree		

Average HU	Average SD

Maximum Deviation	Maximum Deviation (%)

3. UNIFORMITY EVALUATION (Required at periodic and acceptance test.)

Technique used: ________ mA
________ sec
________ kVp
________ slice thickness
Processing Algorithm used: ________________
scan FOV ________ cm
ROI Size ________ mm2

ROI Site	Standard Deviation
isocenter	
0 degree	
90 degree	
180 degree	
270 degree	

Average SD

Maximum Deviation

CATPHAN PERFORMANCE EVALUATION

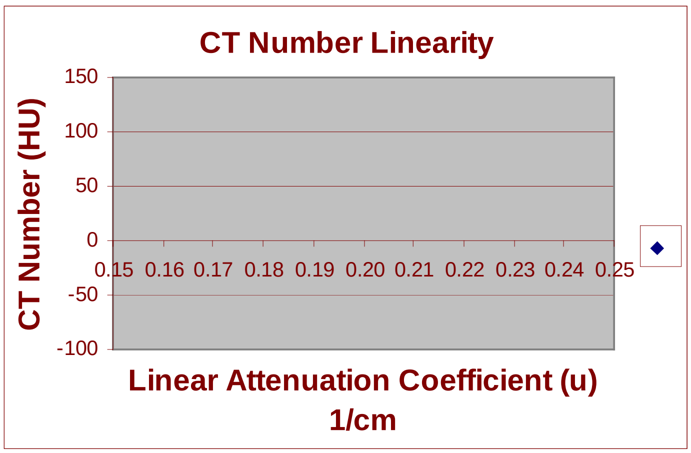
4. LINEARITY EVALUATION (Required at periodic and acceptance test.)

Technique used: ________ mA
________ sec
________ kVp
________ slice thickness

Processing Algorithm used: ____________

scan FOV ________ cm
ROI size ________ mm2

Material	Expected HU value	Measured HU value	Linear Attenuation Coefficient (μ) cm^{-1}
Acrylic	120		0.160
LDPE	-90		0.150
Air	-1000		0.023
Teflon	990		0.302



Correlation Coefficient ________

5. LOW CONTRAST SENSITIVITY (Required at periodic and acceptance test.)

A.

Technique used: ________ mA
________ sec
________ kVp
________ slice thickness
scan FOV ________ cm
ROI Size ________ mm2

Algorithm Used	Contrast (ROI 1)	Contrast (ROI 2)	Percent Contrast	Smallest Hole Resolved (mm)

Revised 01/18/01

CATPHAN PERFORMANCE EVALUATION

5. LOW CONTRAST SENSITIVITY (CONTINUED)

B.

Technique used: ________ mA
________ sec
________ kVp
________ slice thickness
scan FOV ________ cm
ROI Size ________ mm2

Algorithm Used	Contrast (ROI 1)	Contrast (ROI 2)	Percent Contrast	Smallest Hole Resolved (mm)

6. HIGH CONTRAST RESOLUTION (Required at periodic and acceptance test.)

A.

Technique used: ________ mA
________ sec
________ kVp
________ slice thickness
scan FOV ________ cm

Algorithm Used	Number of Bar Patterns Resolved	lp/mm

B.

Technique used: ________ mA
________ sec
________ kVp
________ slice thickness
scan FOV ________ cm

Algorithm Used	Number of Bar Patterns Resolved	lp/mm

7. SLICE SENSITIVITY

Technique used: ________ mA
________ sec
________ kVp
scan FOV ________ cm
Algorithm used ________________

Slice Thickness (mm)	Top	Left	Bottom	Right	Within +/- 1mm of nominal thickness

8. COMMENTS

Appendix G

Film Processor and Darkroom Quality Control

A. Processor Preventive Maintenance and Quality Control

1. Introduction:

a. All processors are best maintained by strictly adhering to the manufacturer recommendations for the proper cleaning and preventive maintenance. Daily and weekly preventive maintenance is usually performed by the local radiology department while monthly "deep cleaning" is performed by a civilian contractor.

b. All preventive maintenance and quality control should be documented in a processor QC log and include any problems with the processor and services performed.

Caution, Secure Power: Prior to performing any daily, weekly or monthly preventative maintenance or QC, turn off the circuit breaker (CB1), located on the processor, and then the main power to the processor.

2. Suggested Procedures:

Safety: Prior to performing these procedures, don protective goggles, rubber gloves and apron.

a. Daily Preventive Maintenance - **Caution**: Handle the processor assemblies with care to prevent changing the alignment. DO NOT use abrasive material on racks, crossover assemblies or squeegee rollers. DO NOT use water exceeding 100 degrees F. To prevent cross-contamination, DO NOT use the same cleaning material for both the fixer and developer sections.

(1) Remove evaporation covers, developer/fixer and fixer/washer crossovers and squeegee assemblies, taking care not to cross contaminate chemicals. Clean with warm water and a soft damp cloth and wipe dry.

(2) Wipe off all chemical deposits on the processing section using a cloth dampened with screen cleaner.

(3) Check all tubing and connections for leaks, loose connections and chemical buildup.

(4) Check processor tank solution level to ensure adequate volume and record in the log.

(5) Check replenishment tank levels to ensure adequate volume and record in the log.

(6) Check developer temperature using a **non-mercury calibrated** thermometer 15-20 minutes after startup, or daily prior to use if processor runs continuously. A digital fever thermometer accurate to at least +/- 0.5% is recommended. The temperature should be within +/- 1 degree Celsius of manufacturer's recommendation (95 degrees F (35 degrees C)). Plot developer temperature.

(7) Replace evaporator covers, crossovers and squeegee assemblies. (Care should be taken to ensure they are replaced in the same position in which they were removed.)

NOTE: When the processor is shut down, leave the top cover open approximately 2 inches at the dryer end to prevent a buildup of moisture and chemical vapors.

(8) Wipe down the feed tray with a cloth dampened with screen cleaner and dry thoroughly.

NOTE: If performing weekly preventive maintenance and QC, skip to "weekly preventive maintenance" below.

(9) Turn on circuit breaker (CB1) and then the main power to the processor.

(10) Prior to processing any patient films, feed four (14 X 17 inch) unprocessed films through the processor to clean up rollers. If the first film comes

out without any roller marks or processor artifacts, no more films are required.

(11) Process sensitometric QC film. (Refer to paragraph f below for sensitometric check procedures.)

b. Weekly Preventive Maintenance -

(1) Perform daily preventive maintenance and QC as described above.

CAUTION: When removing the fixer rack, prevent cross-contamination between the developer and fixer tanks by properly using the splash guard between the two tanks and by using the rack drip trays when removing and installing racks.

(2) With evaporation covers removed, remove all crossover assemblies and all racks. Rinse with hot water and wipe with a clean damp cloth. For detector rack only, clean with a soft fiber brush and clean with warm water. Allow to air dry.

(3) Inspect all racks, gears and rollers for excessive wear. Inspect the rack chain tension and check to see that the rack rollers rotate freely.

(4) Check the space between the turnaround side plates and the rack side plates. The space must be equal and the plates parallel on both ends.

CAUTION: When installing the racks, use splash guard and lower racks slowly to prevent cross-contamination of chemicals.

(5) Install the racks, crossover assemblies and evaporation covers. Ensure each assembly is seated firmly.

(6) Clean the replenisher strainers located between replenisher tanks and pumps.

(7) Check the slots of the air tubes of the dryer for cleanliness and correct orientation.

(8) Turn on the circuit breaker (CB1) and then the main power to the processor.

(9) When the developer light cycles, use a **non-mercury** calibrated thermometer and check the solution temperature in the developer tank. The correct temperature should be 95 degrees F (35 degrees C). For standard processing check manufacturer's instructions for other processing speeds.

(10) Prior to processing any patient films, feed four (14 X 17 inch) unprocessed films through the processor to clean up rollers. If the first film comes out without roller marks or processor artifacts, no more films are required.

(11) Process sensitometric QC film. (Refer to paragraph f below for sensitometric check procedures.)

c. Monthly Preventive Maintenance - Monthly "deep cleaning" of all processors may be performed by a civilian contractor. As part of the deep cleaning, the developer filter and water filter, purchased by Radiology Supply, is replaced by the contractor

d. Processor Servicing - All servicing of processors should be documented on a processor service record.

e. Special Problems:

(1) Contamination of developer with fixer occurs most frequently while removing and reinstalling the racks and while replacing the chemicals during monthly preventive maintenance. If developer does get contaminated, the tank must be drained. Hot water is added to the developer tank and the processor is turned off. This flushes the contaminated recirculation system. The water is then drained. This process is repeated until the recirculating water is clear.

(2) Air gets into the replenishment lines when the level of chemicals in the replenishment tank falls below the opening leading to the processor. This is a problem because the processor can't replenish itself until the air is removed. This can be resolved by first filling the empty replenishment tank to above the outgoing opening. The replenishment line is then followed to the replenishment pump and the incoming line is removed from the pump. The line is then "bled" until all the air is removed from the line. The hose is then reconnected.

(3) If artifacts appear on the film, refer to the film manufacturer's manual for recognition and isolation.

f. Sensitometric Check - should be performed daily on each processor in use as part of processor QC.

(1) Reserve a fresh box of unused film most commonly processed in each processor and label it as "QC" film. For example, the film used in mammography should also be used as the quality control film for the mammography processor.

(2) Expose a sheet of film on opposite edges using a process control sensitometer. The sensitometer will create a multi-step sensitometric control strip on opposite edges of the film.

(3) **Wait thirty minutes after exposing the film before processing** to minimize the effects of latent image fading; this is done by placing the exposed film back in the box.

(4) Use a **non-mercury** thermometer to verify the processor is running at the correct temperature. Process the film and label it with processor ID and date of processing.

(5) The film is now ready to be read using a densitometer.

NOTE: To establish control levels for newly installed processors, processors coming on-line following servicing or extended down time, when using a different type of film, and when a QC program is initiated, expose and process five control films over five consecutive days to obtain accurate averages prior to processing patient films. The mid-density (MD) or density difference (DD) between old and new film should be less than 0.05.

(6) Refer to Table G-1 for an evaluation of Sensitivity Test results:

g. Silver Recovery:

(1) The purpose of silver recovery is to harvest the silver from the film that has been processed and to prevent the dumping of silver into the sewage system.

(2) For monitoring procedures, refer to current silver recovery program instruction and current Precious Metals Recovery Program at your command.

B: Darkroom Quality Control

1. Introduction - Often, the reduction in image quality can be traced back to the darkroom and film storage areas. Light leaks and/or damaged or improper safelights in the darkroom are the most common sources of "fog" on the film. Indicator lights located on electronic equipment can also cause fogging. Dust and other loose material in the darkroom can cause artifacts on film, therefore it is also imperative that the darkroom be kept clean and organized at all times.

2. Suggested Procedures:

a. Ensure darkroom entrance is protected from all direct and reflected "white" light.

b. Ensure ceiling tile material is not flaking.

c. Ensure floor material will withstand chemical spills (applicable if processor and/or chemicals are located in the darkroom).

d. Ensure walls are black or pumpkin-orange in color.

e. Ensure there are non-fluorescent room lights in addition to safelights.

f. Inspect darkroom for light leaks by closing room and turning off all lights. Seal all leaks with black tape or black weather stripping.

g. Ensure air vents are in or near ceiling to minimize dust flowing in room. Vents shall not be located above film handling areas.

h. Ensure darkroom has positive pressure to force out dust and chemical fumes.

I. Check for a deck drain near processors or a catch basin under processors and chemicals.

3. ***Film Storage and Darkroom Cleanliness***

a. **Suggested Procedures**:

(1) Ensure film is stored in a dry area at 50-70 degrees F and is properly shielded from radiation.

(2) Check storage area to make sure boxes of unused film are not stacked on top of each other. Boxes of film shall be stored on edge to minimize

pressure on the individual films. (Films are pressure sensitive.)

(3) Ensure that film is rotated such that the first in is the first to come out, or be used, and that older film is used first.

(4) Remove all clutter from bench tops and from all other work surfaces and wipe down daily. In addition, sweep down floors daily to minimize the amount of dust.

(5) Keep wet (chemical mixing) and dry (cassette load/unload) operations separate.

(6) Vacuum and wipe down vents monthly or as needed.

(7) Change air vent filters monthly or as needed.

(8) Ensure there is no eating, drinking or smoking in darkroom and/or film storage and film processing areas.

4. ***Safelight and Safelight Filters***

a. **Suggested Procedures**:

(1) Check for cracks and other physical damage to safelights and safelight filters and housings.

(2) Replace filters as recommended (usually every 24 months). Use manufacturer's recommendation on type of safelight and filter, filter to tabletop distance and bulb wattage. Filters must match type of film used and must be installed correctly.

5. ***Darkroom QC - Fog Test***

a. The purpose of the fog test is to determine if the conditions in the darkroom will fog the film. This test is performed every six months or when safelight bulbs or housings are replaced. Some sources of fog are light leaks, cracked safelight filters and housings, incorrect bulb wattage in safelights and the safelights being too close to film handling areas.

b. Suggested Procedures:

(1) Turn off all lights and let eyes adjust to darkness.

(2) Open a fresh box of film and expose a sheet of film on opposite edges with a sensitometer.

(3) Place film on counter top directly beneath safelight and mask half of the film with cardboard to cover one of the exposed edges.

(4) Turn on the safelight for two minutes.

(5) Turn off safelight and process film.

(6) Determine the step closest to 1.40 optical density on each of the exposed film edges. The difference in optical density on each edge should not exceed 0.02.

(7) Date, initial and file the film.

(8) Repeat procedure for each type of film used.

6. ***Darkroom QC - Safelight Test***

a. Purpose: To determine the length of time film can be handled under the safelight before processing. This test shall be performed every six months or when safelight bulbs or housings are changed. This is recommended when excessive fogging has occurred or is suspected.

b. Suggested Procedures:

(1) In total darkness, place film in an 8 X 10 inch cassette with screens in place.

(2) Cover half (lengthwise) with a lead mask or lead apron and expose to radiation to obtain an optical density of 0.6-1.0.

(3) In total darkness, remove exposed film and place in Safelight Test Holder. Cover holder completely with cardboard provided. Flaps on this holder will prevent edges of film from being exposed to the safelight.

(4) Turn on safelight and slide cardboard down to first line. Expose to safelight for 4 minutes. Continue sliding cardboard down to adjacent lines for 2 minutes, 1 minute, 30 seconds, 15 seconds and 15 seconds sequentially.

(5) Turn off safelight. Remove the film and process.

(6) View the film. Look closely at the area where the film was exposed to both radiation and safelight. Locate the step "just" noticeably darker than the x-ray exposed background. The time of the cumulative safelight exposure that produced this step is the practical limit for post-exposure safelight handling time. (Actual film handling time should be less to provide a margin of safety.) The part of the test film that received only safelight exposure may be used to determine the safe handling time for unexposed film to prevent visible fog density.

C. Film Cassette Quality Control

1. Introduction - Film cassette quality control and preventive maintenance is very important because image quality can be significantly reduced if cassettes and/or intensifying screens become dirty or damaged.

2. Suggested Procedures:

a. Inventory all cassettes, ensure the outside cassette label and their associated intensifying screens are properly labeled with a unique identification number; i.e., the same number on both the cassette and its screen. Intensifying screens shall be labeled in the upper right corner using a black indelible marker.

b. Clean each cassette and intensifying screen with a soft lint- free cloth dampened with an anti-static screen cleaning solution and allow to air dry in a vertical position ensuring no lint remains on the screen or in the cassette.

c. Visually inspect each cassette and each intensifying screen for scratches, cracks and other physical damage. If significantly damaged, remove from service.

d. Perform film/screen contact test on all cassettes semi-annually by placing the film/screen contact test tool directly on top of each loaded cassette and making an exposure, using techniques such that a medium density image of the mesh can be seen on each film after processing. Identify areas of poor contact by examining the films on a viewbox, looking for blurred areas greater than 1 cm in diameter. Remove from service all cassettes with poor film/screen contact.

Table G-1: Evaluation of Film Sensitivity Test

	BASE + FOG	SPEED INDEX	CONTRAST INDEX
Allowable density differences[1] (normal processor variations)	Less than 0.03 optical density	Less than 0.15 optical density	Less than 0.15 optical density

[1]Density differences greater than that indicated require immediate analysis. A trend exists if a series of consecutive points progresses steadily upward or downward. Such a trend may be a shift taking place slowly and visibly over time. Trends or gross fluctuations should be noted and evaluated. Appropriate action should be taken and documented if necessary.

Appendix H

Repeat Rate Analysis

A. Techniques:

1. Different category schemes may be used to separate repeat films. For example, all the repeats should contain at a minimum according to cause:

   a. technique error
   b. positioning error
   c. motion
   d. darkroom error
   e. too light or too dark
   f. static
   g. cassette/mechanical problems
   h. waste
   i. others: (double exposure, inadequate information)

2. Alternatively, identification of the technician or level of training may be included. Table H-1 illustrates one classification system. If identified by name, take care to do the analysis in a non-threatening way. If a technician feels he/she will be singled out for repeat films, these films may never be found in the repeat film collection box because of the technician's fear of consequences. This may lead to delayed identification of needed areas for training and poor patient care.

B. Analysis

1. Once a system has been chosen to categorize repeat films and one person has been chosen to mark each film as to its category, the numbers obtained are recorded each day in the department log. At the end of a month, a QA representative analyzes the number of repeat films accumulated over the month as listed in the log.

C. Method

1. Find the total number of films taken. Most Navy Medical Treatment Facilities (MTF) are on a computer system which will record automatically the number of studies done that month as well as the average number of films/exam. This gives the total number of films taken if there is a zero repeat rate.

2. The repeat rate equals the number of repeat films divided by the total number of films taken during the month and is recorded as a percentage.

3. At most shore-based MTF's, the percentage is recorded and sent to Quality Improvement in the monthly QI report. Trend analysis is done graphically so comparison with previous months may be done. Also included are actions taken. Actions taken are based on probable causes, i.e., why is there a change in the repeat rate from last month.

4. The repeat rate should be less than 10%. Ten percent is an established norm nation-wide. As an aside, the repeat rate for mammography is between 2-5%. Many departments have succeeded in obtaining repeat rates much lower than 10%; the more detailed the quality assurance, the more likely that the average rate will be reduced.

D. Causes of fluctuation of repeat rate

1. Many factors contribute to the observed repeat rate. Included among these are:

   a. Changes in processor chemicals

   b. Changes in x-ray student classes working on the floor (Phase II students)

   c. Patient difficulty (e.g., acutely ill patients)

   d. Type of study, e.g., exotic studies (SI joints or mastoids, i.e., any exams not routinely done).

   e. Introduction of a new exam type. Processor maintenance - cleaning schedule, operating temperature, contaminants.

2. The most common problems are technique and positioning. For example, it is easy to clip an image. Also, proper technique for different size

patients can be difficult to estimate and may lead to additional shots. Processor problems also are an important source of poor quality films requiring reshooting.

E. <u>Advantages of controlling repeat rate at less than 10% or as low as possible</u>:

a. Lower dose to patient.
b. Less film needed.
c. Less patient waiting time.

F. <u>Example:</u>

1. At a Naval Medical Center, there is a full-time QC technician responsible for the repeat rate analysis program. Films accidentally exposed to visible light are called waste films and not included in the analysis. Repeat films are called TU films (for technically unsatisfactory) and dropped into a centrally located box. The QC technician marks the film TU, why the film is TU and who made the film. Once a day (usually on the night shift), the films are sorted according to the categories in Table H-1 and the numbers recorded in the department log.

2. At the end of the month the QA representative or designee compiles the numbers and determines the total number of legitimate radiographs ordered during the month. This number is calculated from TRIRAD data covering film utilization.

3. The TRIRAD print-out is adjusted as follows: Exposures taken at Branch Medical Clinics are deleted from the total as are procedures involving digital recording, such as computed tomography, angiography, ultrasound, magnetic resonance imaging, nuclear medicine and radiation therapy. Mammography is calculated separately by the certified mammography tech.

4. The repeat analysis percentage may be calculated using spreadsheet software. Table H-2 is an example from a spreadsheet.

Table H-1

Technically Unsatisfactory (TU) Film Categories
(Sample)

Abbreviation	TU Film Category
Waste (W)	**Waste**
PTS	**Patient motion or lack of patient cooperation.**
TEC POST (TP)	**Staff technician positioning error.**
TEC TECH (TT)	**Staff technician technique error.**
SS POST (SSP)	**Senior student positioning error.**
SS TECH (SST)	**Senior student technique error.**
JS POST (JSP)	**Junior student positioning error.**
JS TECH (JST)	**Junior student technique error.**
OJT POST	**Positioning error by command trained personnel.**
OJT TECH	**Technique error by command trained personnel.**

Table H-2

Monthly Waste and Technically Unsatisfactory (TU) Rate (example)

DAY	WASTE	PTS	TEC POST	TEC TECH	SS POST	SS TECH	JS POST	JS TECH	OJT POST	OJT TECH
1	37	6	25	11	30	26	5	3	0	0
2	15	3	9	10	23	34	6	4	1	2
3	135	9	22	49	17	40	4	10	2	2
4	20	31	12	23	21	23	11	2	4	8
5	26	4	15	22	19	26	6	5	2	3
6	12	2	7	15	5	7	8	13	2	3
7	11	1	7	5	11	10	5	9	2	3
8	56	3	17	21	34	31	10	12	2	3
9	56	2	14	17	30	28	5	6	1	3
10	82	1	9	11	26	35	8	13	1	1
11	14	2	9	5	9	7	8	7	1	0
Day 11, day 12 etc. ↓ until the end of the month										
TOTAL	1120	104	378	431	542	543	97	101	18	40

Summary:

Total TU: 2254
Total Waste: 1120
Total Discard: 3374

Total Exposures	÷	Total TU	=	TU Rate
(25223	÷	2254	=	11.99)

1. Patient TU's are not counted in the Total Waste or TU rate.
2. Total exposures are calculated from TRIRAD "FM Option 1", deleting CT, AN, US, MR, RT, and CL.
3. With a good quality control program in place, poor radiographs may no longer be vaguely attributed to electrical line surges, unpredictable processors and the darkroom technician.

Appendix I

Entrance Skin Exposures

A. Entrance Skin Exposures for General Radiographic Equipment

1. Purpose: To ensure that entrance skin exposures (ESE) for standard radiographic techniques are within standards.

2. Regulations: Naval Environmental Health Center (NEHC) publishes national averages for the standard radiographic techniques. Joint Commission for Accreditation of Healthcare Organizations (JCAHO, 1994) requires ESE's, for techniques used most commonly, be evaluated on an annual basis.

3. Procedure

a. ***Manual Mode***

(1) In addition to the procedures outlined below, the following parameters must be known for each tube head to obtain specific organ doses:

(a) Source-to-skin distance
(b) Source-to-image receptor distance
(c) Technique factors for the selected projection
(d) HVL of the unit in question for the selected projection

(2) Set the clinically used SID. Center the ion chamber in the x-ray field at approximately 23 cm above the tabletop to minimize backscatter. Record the distance from the focal spot to the center of the ion chamber.

(3) Collimate the light field on the ion chamber using narrow beam geometry.

(4) Set the desired technique factors at the control panel.

(5) Expose the ion chamber and record the free-in-air exposure.

(6) Repeat as necessary for other commonly used projections and technique factors.

(7) Calculate the entrance skin exposure for each projection using the patient thickness guidelines in table 2 of HHS Publication (FDA) 89-8031 and the inverse square law. The inverse square calculation is as follows:

$$ESE = \left(\frac{x_1}{x_2}\right)^2 \times FIA$$

Where:

ESE = corrected x-ray beam intensity at the skin entrance
x_1 = focal spot to center of ion chamber distance
x_2 = distance from the focal spot to the surface of the skin ($x_2 = x_1$ - patient thickness)
FIA = Free in air exposure at the center of the ion chamber

(8) Interpretation of Results: Compare exposures received for standard techniques with the NEXT published national guidelines and rate as satisfactory or unsatisfactory. If exposures are not within recommended ranges, an evaluation of image quality should be conducted in consultation with the clinical staff. Factors such as: types of grids, types of screens, processor quality control, preference of clinical staff, and whether the x-ray unit meets all other performance test requirements should be evaluated. A qualified service engineer should be consulted for equipment adjustment.

(9) To determine tissue/organ doses for projections common in diagnostic radiology, use the ESE for each projection, the additional information in item 3.1 above and refer to HHS Publication (FDA) 89-8031.

(10) To estimate the dose to the embryo-fetus from radiographic examinations, refer to reference HHS Publication (FDA) 79-8079 and NCRP Report 54.

b. ***Automatic Exposure Control Mode***

(1) Measure and record the Half value layer of the X-ray beam.

(2) Set up X-ray unit for normal radiographs: chest, abdomen, and extremity.

(3) Place the patient phantom over the selected AEC detectors. (see figures I-1a and I-1b, shown for a chest unit)

(4) Place the ion chamber detector in the test stand's top position nearest the X-ray tube. Place the test stand flush on the table against the chest bucky. (Ensure that the detector does not cover the AEC sensor).

(5) With the ion chamber meter in pulse exposure mode; take an exposure at the kVp setting used for an average adult X-ray.

(6) Record the exposure on the data form along with the following distances:

a) Source to detector.
b) Source to film.

(7) Follow the steps in 3.(a)(7) through 3.(a)(10) above to calculate ESE, interpret results and to estimate organ dose/embryo-fetal doses.

B. <u>Entrance Skin Exposures for Dental Intraoral Units</u>

1. <u>Procedure</u>:

a. Place the probe about one inch from end of cone.

b. Use a technique commonly used on the machine to make an exposure. This is the ESE which should be recorded along with all settings used.

c. Record focal spot to chamber distance which represents the source to skin distance and approximates the source to image distance. Use the actual kVp as determined.

C. <u>Entrance Skin Exposure Rates for Fluoroscopy Units</u>

1. <u>Procedure</u>:

a. Refer to Appendix D, section A.2. for fluoroscopic entrance exposure rate measurement procedures. Tolerances are listed in Table D.3.

Note that 1100 alloy aluminum sheets are less suitable as a fluoroscopy ESE rate phantom than acrylic slabs since the aluminum represents significantly different equivalent patient thicknesses at different kVp values. Aluminum also does not provide the same amount of scatter as the thicker acrylic block. Experimental data has demonstrated up to 2X higher ESE rates using acrylic. However, not all evaluators will have acrylic phantoms in their equipment inventories. To maintain consistency, clearly identify the type of phantom used, record the testing conditions, and perform subsequent evaluations using the original phantom and conditions.

D. <u>Digital/Mechanical Spot Film ESE</u>

1. <u>Introduction</u>:

a. Fluoroscopy is routinely used as a localization mechanism for radiographic images that are analyzed at a later time. In many fluoroscopic examinations, the radiographic spot film exposure component can be substantial, especially if the use of contrast is involved. Therefore, accurate spot film entrance skin exposure (ESE) measurements are essential to maintaining a database for determining patient exposures.

b. Digital spot film exposure measurement assumes proper generator calibration and satisfactory operation of the imaging chain components. Image intensifier entrance exposure rate (μRfr^{-1}) must be properly set to the manufacturer's recommendation. For mechanical spot film devices, proper AEC subsystem operation is essential. For these reasons, spot film ESE testing is typically performed last during an acceptance inspection or annual performance evaluation.

2. Procedure:

a. Arrange the fluoroscopy unit and ion chamber in the configuration appropriate to the machine type; i.e. undertable tube, overtable tube, or C-arm. Appendix D, section A.2.c. applies. Ensure that if a grid is used in clinical studies, it is in the beam path during testing. If the system is equipped with a manual spot film device, place a loaded cassette in the II tower.

b. Place a 4 cm aluminum or 15 cm acrylic phantom in the beam in the same manner as for measuring entrance skin exposure rate. Ensure that the phantom sits between the ion chamber and the image intensifier tube.

c. If the unit provides specific spot film routines for different anatomical applications, program the system for non-contrast abdominal studies. If different dose levels are also provided, select a medium setting. If anatomical or dose programming are not provided, use the system's automatic brightness control (ABC) to determine the kVp to be used during testing. For manual only systems, program the unit for 80 kVp. Select an appropriate medium level current (e.g. 200 mA). Program a digital spot film system to operate at its minimum frame rate (1 frs^{-1} is most desirable). If appropriate, set the mechanical spot film device to terminate exposure using AEC.

d. Set the image intensifier to minimum size, collimating to the phantom dimensions if necessary. Fluoro the phantom briefly, allowing ABC to select an appropriate kVp. Several systems apply the ABC selected voltage directly to the spot film technique. For those that do not, the fluoro kVp serves as a useful baseline for manual spot film technique programming.

e. Irradiate the phantom and ion chamber using digital spot mode, recording the measured ESE and actual mAs. During acceptance, repeat for all available II sizes and dose settings, as applicable. During annual evaluations, test at the most commonly used dose setting using the largest II size.

f. For those units with an additional mechanical spot film device, measure ESE using the same kVp and mA as for the digital spot, but collimate the radiation field to match the largest II size. During acceptance, repeat using all available II sizes.

g. For pediatrics rooms, repeat the procedure using a 2 cm aluminum or 8 cm acrylic phantom thickness.

h. If spot films are made with and without a grid in the beam, repeat the procedure with the grid removed from the beam.

3. Interpretation of Results: Calculate an ESE rate as a function of mAs. Determine maximum, minimum, and average exposure/mAs. If current values differ from their acceptance or historical counterparts by more than ± 10 %, refer the system for adjustment by a qualified service engineer.

E. Linear Tomography

1. Purpose: Image mottle and resolution may be improved by increasing the photon fluence rate. This improvement in image quality is done at the expense of radiation dose to the patient. Tomography, especially thin section tomography (e.g., inner ear) may result in a total exposure between 12 R to 17 R for the series of films required. To minimize the dose to the patient, evaluation of entrance skin exposures (ESE) are performed for clinically used.

ENTRANCE SKIN EXPOSURE
(Data Sheet)

Location:______________________________________ Date:____________

Room #:_______________________________________

Unit:
Make:____Model:____________

Control Console Serial Number:______________________

Tube:
Make:____Model:____________

Serial #:______________ Configuration:______________

Detector:
Make:____Model:_____________

Serial #:______________ Calibration Date:__________

X-ray beam HVL (mm Al)	kVp	Exposure (mR)	Source to Detector Distance (inches)	Source to Film (inches)	Calculated ESE (mR)	Overall Evaluation Sat Unsat

Entrance Skin Exposure
Evaluation Performed by:_______________________________

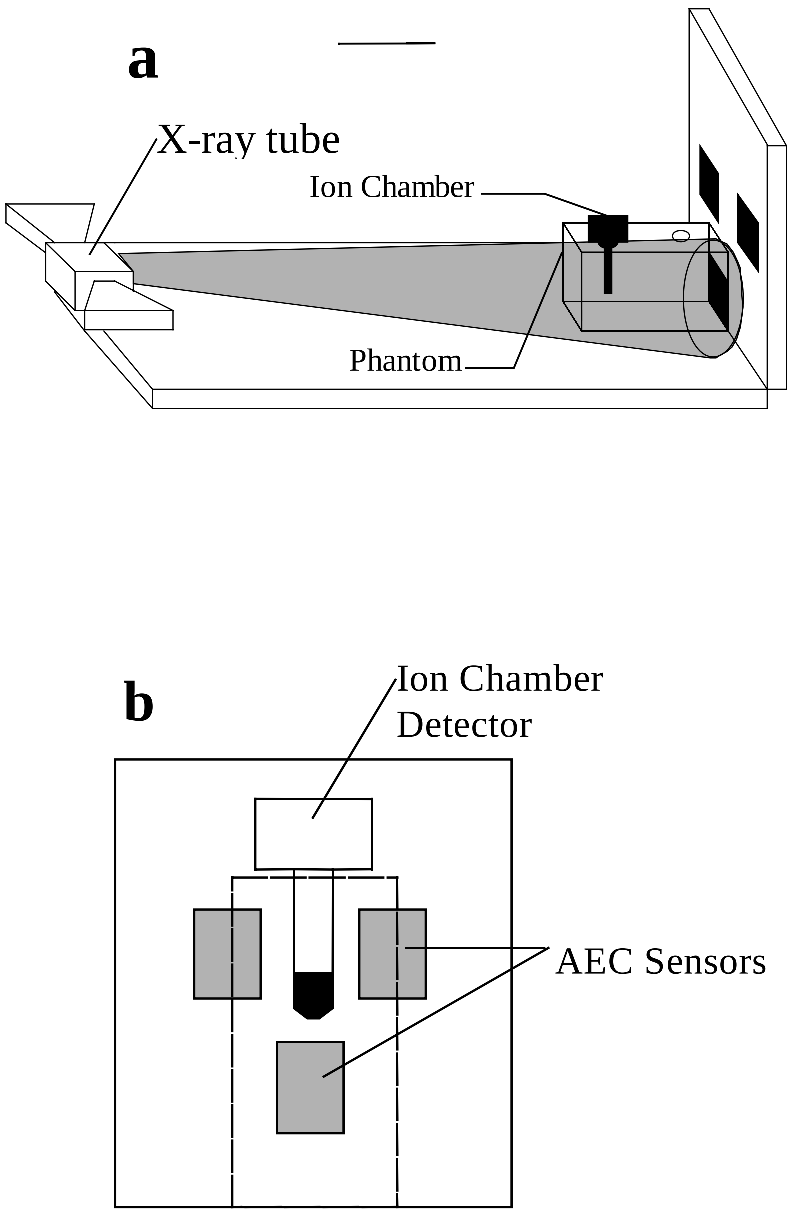


Figure I-1: Equipment Configuration for Chest Unit AEC Entrance Skin Exposure Calculation

Appendix J

Radiation Shielding Design and Evaluation for Medical and Dental X-Ray Facilities

A. General Requirements for Medical Diagnostic X-Ray Facilities Ashore

1. *Introduction*

a. Purpose: This appendix is provided to assist in the calculation of a shielding design for a diagnostic x-ray facility. The design shall yield the thickness and type of shielding required to adequately shield the general public against man-made sources of radiation.

b. Regulations: The Navy Radiation Protection Manual requires that the effective dose to a given member of the general public does not exceed 100 mrem per year from man-made sources of radiation.

c. Equipment: Tape measure, room layout, calculator, and electrometer with large ion chamber.

d. Procedure: Initially several variables must be determined for the facility. They include obtaining an accurate facility layout with an appropriate measurement scale. A description of spaces for rooms adjacent to the x-ray suite, including spaces above and below the suite must be obtained. The occupancy factor, T, for each area must be determined (see section J.2.) The design dose limit, P, shall be determined for each area (see section J.3.) The workload and number of patient per week shall be determined (see section J.4.) After all of the information above has been obtained an accurate shielding design can be calculated.

e. Interpretation of results: Shielding thickness and type shall be evaluated to ensure that they provide sufficient barriers for the x-ray facility. Future TLD results from devices placed outside the room will verify that the room has been properly shielding for members of the general public.

2. *Occupancy Factors, T*

a. Purpose: To ensure that the appropriate occupancy factor, T, is selected for each area.

b. Definition: The occupancy factor, T, for an area is defined as the fraction of the radiation exposure to the area which is delivered while a given (maximally exposed) individual is present. This is averaged over a one-year period. This allows the average radiation level in a partially occupied area to be higher than that for a fully occupied area by a factor of 1/T. The occupancy factor is not the fraction of time that any person occupies an area but the faction of time it is occupied by a single person.

c. Equipment: Description of area.

d. Procedure: An estimate of the maximum amount of time in hours a given person is likely to occupy a space in an eight hour working day (averaged over a year), divided by 8 hours shall be determined for each area. Tables J-1 and J-2 provide examples of occupancy factors for non-occupationally exposed persons and occupationally exposed persons, respectively.

e. Interpretation of results: The designer must pay particular attention when assigning a low occupancy factor to an uncontrolled area immediately adjacent to an x-ray room. The actual limitation for the shielding design may be a fully occupied area further removed from the x-ray room (such as an office space across the corridor).

3. *Design Dose Limit, P*

a. Purpose: To ensure that the appropriate design dose is selected for each area.

b. Definition: The design dose limit for an area will depend on whether the area is a controlled or uncontrolled space. The design dose limit for uncontrolled spaces shall be 2 mrem (20 μSv) per week and controlled spaces shall be 10 mrem (100 μSv) per week.

c. Equipment: Description of area.

d. Procedure: Uncontrolled areas shall have a minimum occupancy factor of 1/40 to ensure that an individual member of the general public receives no more than 2 mrem (20 μSv) in a one-hour period. Therefore shielding an uncontrolled area with an occupancy factor of 1/40 to the design dose limit, P, of 2 mrem per week would then deliver no more than 2 mrem in any one hour of a 40-hour work week and no more than 100 mrem per year.

e. Interpretation of resutls: A conservative approach shall be taken when assigning the design dose limit for an area so that the partial occupancy of a radiation worker which can result in a greater dose does not exceed the dose of a member of the general public and vice versa.

4. ***Workload Distribution and Number of Patient Exams***

a. Purpose: To ensure that the appropriate workload distribution, W, and the appropriate number of patient exams, N, are assigned.

b. Definition: NCRP Report 49 uses a single kVp of 100 to calculate the recommended thickness and type of shielding. However, Task Group 9 of the X-ray Imaging Committee of the AAPM, found that a more realistic distribution is found centered around 80 kVp.

c. Equipment: Description of workload and number of patients exam performed at the facility.

d. Procedure: The actual workload distribution for a particular facility will vary. The workload distributions are scaled per patient exam; therefore, the factor that is most important is the determination of the number of patient exams per week.

e. Interpretation of results: It should be noted that the figures and tables reproduced from the references break the workload distribution into two components. They are the workload directed toward the vertical cassette assembly that occurs at greater potentials and the workload directed at the other barriers in the room that occurs at lower potentials. The normalized radiation dose per workload and the transmission curves have been separately analyzed for these distributions.

5. ***Use Factor, U***

a. Purpose: To ensure that the appropriate use factor, U, is assigned to each barrier.

b. Definitions: The use factor, U, is the fraction of the x-ray tube's total workload that is expended upon a particular primary barrier.

c. Equipment: Description of barrier.

d. Procedure: Typically the use factor for the chest bucky wall is 1. The remaining floor/all other barriers typically have use factors of 0.89 for the floor, 0.09 for the cross-table wall, and 0.02 for a third, unidentified wall.

6. ***Calculation of the Primary Barrier***

a. Purpose: To assure that the appropriate thickness and type of shielding is yielded for the shielding design.

b. Definition: Since the image intensifier and the breast support tray in mammography are required to act as primary beam stops, primary shielding barriers are only applicable for radiographic rooms or the overhead tube in a conventional radiographic and fluoroscopic room. These include the wall on which the vertical cassette holder assembly is mounted and the floor and remaining walls.

c. Equipment: All previous information.

d. Procedure: The unshielded primary dose, Dp1, per patient at 1 m in mGy is provided in Table J-3. These values are reproduced from Dixon and Simpkin. The values were obtained by integrating over the workload distributions using a weighting function equal to the x-ray dose per workload. Figures J-1 through J-5 are curves of the primary beam transmission, Bp(x), for each workload distribution for lead, concrete, gypsum board, steel and plate glass. The curves were calculated by summing the incremental dose in each kVp interval transmitted through a given barrier thickness and dividing that by the dose expected with no barrier. The weekly unshielded dose in the occupied area due to N patient exams per week performed in the room is:

$$D_p(0) = \frac{D_p^1 N}{d_p^2} = \frac{D_p^1 U W_{tot}}{d_p^2 W_{norm}}$$

1. Primary Barrier Calculation for the Floor: The required primary barrier thickness should be calculated for the floor utilizing the below equation.

$$B_P(x + x_{pre}) = \left(\frac{P}{T}\right)\frac{d_p^2}{D_p^1 N} = \left(\frac{P}{T}\right)\frac{d_p^2 W_{norm}}{D_p^1 U W_{tot}}$$

Assuming that the x-ray table, cassette and cassette holder intercepts the primary beam the barrier equivalency of these can be subtracted from the required barrier thickness. A typical x-ray table with a cassette in the cassette holder has a lead equivalence in excess of 0.8 mm and a concrete equivalence in excess of 7 cm. Table IV provides equivalent thicknesses for lead, concrete, gypsum board, steel, and plate glass.

2. Primary Barrier Containing the Wall-Mounted Cassette Holder: A typical wall mounted cassette holder also contains a considerable amount of steel and provides significant attenuation. A similar shielding calculation should be preformed for this wall and an appropriate barrier equivalence thickness can be subtracted to obtain the required primary barrier thickness.

e. Possible Pitfalls: The designer should determine if "light-weight" concrete was used in the construction of the facility. Normal density concrete is 2.35 g/cm3 and "light-weight" concrete density is 1.8 g/cm. Therefore, approximately 31% more "light-weight" concrete is required to achieve the same shielding ability.

f. Interpretation of Results: A degree of conservatism is maintained since the attenuation of the patient is not considered.

7. ***Calculation of Secondary Barrier***

a. Purpose: To assure that the appropriate thickness and type of shielding is yielded for the shielding design.

b. Definitions: All barriers not considered to be primary barriers will be treated as secondary barriers. Secondary barriers have two possible sources of radiation exposure. They are scatter and leakage radiation. The radiation dose due to scatter is determined from the knowledge of the scatter fraction which is a ratio of the scatter dose 1 m from the center of the patient to the primary dose 1 m from the s-ray tube. The radiation dose due to tube housing leakage is limited by the FDA. The lead equivalence of the tube housing must reduce the leakage at 1 m to 100 mR/hr when the tube is operated at its leakage technique factors. These factors are the maximum kVp, and the maximum mA allowed at the maximum kVp for continuous tube operation.

c. Equipment: All previous information.

d. Procedure: The scatter and leakage doses are computed separately. The procedures are outlined below.

1. Tube Housing Leakage: The leakage radiation beam has been significately hardened by the lead in the tube housing. Therefore, the penetration through structural shielding barriers must be computed using higher half-value thicknesses at high attenuation. Table J-5 provides the "unshielded" leakage dose per patient at 1 m.

2. Scatter: The scatter dose scales with the primary beam area F, known at primary distance d_F. These values are provided in Table J-5.

3. Total Secondary Radiation Dose: The unshielded scatter, leakage, and total secondary doses, D_{sec}^1, are provided in Table J-5. They are calculated for operation at single potentials and for the clinical workload distributions fro the case where the scatter and leakage distances are the same, and equal to d_{sec}. The calculated transmission curves, Bsec, fro secondary radiation through various shielding materials for the different workload distributions

are provided in Figures J-6 through J-11. The secondary transmission exceeds the primary for the same barrier thickness because of the inclusion of leakage. The following equation provides the unshielded secondary dose for N patients:

$$D_{sec}(0) = \frac{D_{sec}^{1} N}{d_{sec}^{2}} = \frac{D_{sec}^{1} W_{tot}}{d_{sec}^{2} W_{norm}}$$

The required secondary barrier thickness x can be calculated by using the following equation:

$$B_{sec}(x) = \left(\frac{P}{T}\right) \frac{d_{sec}^{2}}{D_{sec}^{1} N} = \left(\frac{P}{T}\right) \frac{d_{sec}^{2} W_{norm}}{D_{sec}^{1} W_{tot}}$$

8. ***Example Calculation***

A sample calculation is available from the Department of Radiology at the Uniformed Services University of the Health Sciences.

B. General Requirements for Medical and Dental X-Ray Facilities Afloat

1. *Introduction*

a. Purpose: This section is designed to assist in the calculation of a shielding design for afloat diagnostic medical and dental x-ray facilities. All of the definitions and equations provided previously are still valid. Two additional references are applicable, they are: General Specifications for Ships of the United States Navy, Department of the Navy, Naval Sea Systems Command (1994 Edition) and General Specifications for Overhaul of Surface Ships (GSO), Department of the Navy, Naval Sea Systems Command (S9AA0-AB-GOS-010 1990 Edition). The recommendations are applicable for new construction and overhaul.

b. Definitions: Medical and dental x-ray machines generate a broad x-ray photon spectrum with a transmission factor of 6×10^{-3}, where standard decking plate of 1/4 inch steel or 1/32 inch lead sheet provide sufficient primary and secondary (leakage and scattered) x-ray beam attenuation. These thicknesses are stated as minimum values. If 1/16 inch lead sheeting is more cost effective than the specified 1/32 inch lead sheet, it is appropriate to substitute the thicker lead sheeting. All shielding shall extend to 7 feet above the finished deck. It is acceptable to run the shielding to the overhead. The following specific recommendations are provided for shielding of shipboard dental and medical spaces.

2. *Dental x-ray spaces*. The General Specifications for Ships and General Specifications for Overhaul specify that dental x-ray rooms with type 4 bulkheads and type E overhead sheathing shall have appropriate shielding of all space boundaries (bulkheads, overhead, and deck). Specific guidance for each space boundary follows.

a. Deck and Overhead. Normal deck and bulkhead construction consisting of 1/4 inch steel plate meets the protective barrier shielding requirements for the deck and overhead of dental x-ray rooms. No further shielding is required.

b. Bulkheads. All dental x-ray room bulkheads shall be constructed of 1/4 inch steel sheet or be shielded with 1/32 inch lead sheet.

c. Operator's Control Position. The operators control station should be in a separate room or a protected booth. Additionally, it may be located in a passageway outside of the x-ray room. The control area must be constructed with a bulkhead of 1/4 inch steel sheet or be shielded with 1/32 inch lead sheet. Provision shall be made for the operator to clearly observe and communicate with the patient from the shielded position. When an observation window is provided in the protective bulkhead it shall have a lead equivalency of 1.5 mm. The observation window shall not be less than 12 inches square and shall be centered 5 feet above the finished deck. When a protective door is not required, the edge of the observation window shall be at least 18 inches from the edge of the control partition. The exposure switch shall be located so it cannot be conveniently operated outside the shielded area.

d. Entry Door. No additional shielding is required for door entries/hatches leading from the passageway into the dental x-ray room. The typical shipboard metal joiner door constructed of 0.064 inch aluminum may be utilized. If no entry door is provided to the dental x-ray room a detachable web strap that spans the opening shall be provided. A sign “NO ENTRY, X-RAY MACHINE IN OPERATION” shall be attached to the strap so that the top of the sign is 52 inches above the finished deck.

3. Medical x-ray spaces. The General Specifications for Ships and General Specifications for Overhaul specify that medical x-ray rooms with type 4 bulkheads and type E overhead sheathing shall have appropriate shielding of all space boundaries (bulkheads, overhead, and deck). Specific guidance for each space boundary follows.

a. Deck and Overhead. Normal deck and bulkhead construction consisting of 1/4 inch steel plate meets the protective barrier shielding requirements for the deck and overhead of medical x-ray rooms. No further shielding is required.

b. Bulkheads. All medical x-ray room bulkheads shall be constructed of 1/4 inch steel sheet or be shielded with 1/32 inch lead sheet.

c. Operator’s Control Position. The operators control station should be in a separate room or a protected booth. Additionally, it may be located in a passageway outside of the x-ray room. The control area must be constructed with a bulkhead of 1/4 inch steel sheet or be shielded with 1/32 inch lead sheet. Provision shall be made for the operator to clearly observe and communicate with the patient from the shielded position. When an observation window is provided in the protective bulkhead it shall have a lead equivalency of 1.5 mm. The observation window shall not be less than 12 inches square and shall be centered 5 feet above the finished deck. When a protective door is not required, the edge of the observation window shall be at least 18 inches from the edge of the control partition. The exposure switch shall be located so it cannot be conveniently operated outside the shielded area.

d. Bulkhead with vertical cassette holder/bucky. If the bulkhead supporting the vertical film cassette holder/bucky has adjoining manned spaces it shall have an additional 1/32 inch lead sheet added to the protective barrier for a total lead thickness of 1/16 inch. This additional shielding must extent beyond the horizontal and vertical edges of the vertical cassette holder/bucky by at least 18 inches.

e. Entry Door. Entry into the medical x-ray room must be via a door that can be closed and locked. This door must be shielded with 1/32 inch lead sheet. If the door is located on a bulkhead shielded with greater than 1/32 inch lead sheet, the door shall be shielded with the same lead thickness.

C. <u>General Requirements for Dental Facilities</u>

*1. **Introduction***

a. Purpose: This section is designed to assist in the calculation of a shielding design for dental x-ray facilities. All of the definitions and equations provided previously are still valid. One additional reference is applicable entitled Dental X-ray Protection, National Council on Radiation Protection and Measurements Report No. 35, issued March 9, 1970.

2. *Calculation of the Primary Barrier*. All previous equations provided in section A apply. Tables J-6 and J-7 provide lead and concrete primary barrier thicknesses respectively for full, partial, and occasional occupancy for various workloads.

3. *Calculation of the Secondary Barrier*. All previous equations provided in section A apply. Tables J-8 and J-9 provide lead and concrete primary barrier thicknesses respectively for full, partial, and occasional occupancy for various workloads.

4. Special Installations

a. Panoramic Installations. Due to the narrow useful beam and the shielding of the film carrier structural shielding is not typically required. If high workloads are anticipated a shielding design should be calculated to ensure the proper structural shielding is recommended.

b. Cephalometric Installations. The recommendations provided in section C.2 and C.3 shall be followed to calculate an adequate shielding design.

D. General Requirements for Mammography Facilities (under construction)

Table J-1: Suggested Occupancy Factors[a] For Non-Occupationally Exposed Persons (reproduced from reference 9)

Uncontrolled Areas

Location	T
Offices, shops, living quarters, children's indoor play areas, occupied space in nearby buildings	1
Laundry	1
Attended waiting room[c]	1
Nurses stations	1/2
Patient exam and Treatment rooms	1/2
Kitchens	1/2
Cafeterias	1/2
Patient rooms[b]	1/8
Corridors	1/8
Employee lounge	1/8
Rest rooms or bathrooms	1/20
Unattended vending areas	1/20
Storage rooms	1/20
Outdoor areas with seating	1/20
Outdoor areas with only transient pedestrian or vehicular traffic	1/40
Unattended parking lots	1/40
Vehicular drop off areas (unattended)	1/40
Attics	1/40
Unattended waiting rooms	1/40
Stairways	1/40
Unattended elevators	1/40
Patient Dressing room	1/40
Janitors closets	1/40

[a] Care should be taken when using a low occupancy factor for a room immediately adjacent to an x-ray room to also consider the areas further removed from the x-ray room which may have significantly higher occupancy factors and may therefore represent the limitation for shield design despite the larger distances involved.

[b] Limited by attending nursing staff—not by patients and families.

[c] Limited by attendant

Table J-2: Occupancy Factors For Occupationally Exposed Persons (reproduced from reference 9)

Controlled Areas

Location	T
X-ray control booth	1
Film reading area	1
Ultrasound Exam room	1
Nuclear Medicine scan room	1
Other offices	1
Workroom	1
Employee lounge	1
Adjacent x-ray room	1
Medical staff office	1/2
Radiology administrator or chief tech's office	1/2
Barium kitchen	1/2
Rest rooms	1/4
Corridor	1/4
Patient holding areas	1/4
Patient dressing rooms	1/8

Table J-3: Unshielded primary dose, D_P^1, (mGy) for the indicated workloads, W_{norm}, and workload distributions, at primary beam distance d_p = 1 m. These primary doses ignore the attenuation available in the image receptor in radiographic table or vertical cassette holder assembly. For the indicated clinical installations, W_{norm} is the average workload per patient, and the workload distributions are those surveyed by Task Group 9 of the X-ray Imaging Committee of the AAPM[3]. (reproduced from reference 9)

Workload Distribution	W_{norm} Total Workload per patient (mA·min)	D_P^1 Unshielded Primary Dose per patient (mGy) at d_p = 1m
Radiographic Room (all barriers)	2.45	7.41
Radiographic Room (chest bucky wall)	0.601	2.25
Radiographic Room (floor/other walls)	1.85	5.15
Overhead radiographic tube in Rad/Fluoro Suite	1.51	5.85
Chest Room	0.216	1.21

Table J-4: Equivalent thickness, x_{prr}, of the radiographic table image receptor and vertical cassette holder assembly for clinical installations surveyed by Task Group 9 of the X-ray Imaging Committee of the AAPM [3]. Thickness in mm. Determined from transmission data from Dixon [4]. (reproduced from reference 9).

	Equivalent thickness of radiographic table/image receptors, x_{pre} (mm)				
Type of Installation	Pb	Concrete	Gypsum	Steel	Plate Glass
Radiographic Room (all barriers)	0.87	73	230	7.1	84
Radiographic Room (chest bucky wall)	0.85	72	230	7.4	83
Radiographic Room (Floor/other walls)	0.94	74	235	7.0	88
Radiographic Tube in R&F room	0.86	73	230	7.5	83
Chest Room	0.91	72	230	7.5	86

Table J-5 Unshielded secondary doses, D_{sec}^{1}, (mGy) for the indicated workload distributions at $d_S = d_L =$ 1m

	W_{norm}			D_{sec}^{1}, Unshielded Secondary Dose (mGy) per workload W_{norm} at 1 m				
Workload Distribution	Total Workload (mA·min)	F (cm^2)	at d_F (m)	Leakage	90° Scatter	90° Total	30°, 135° Scatter	30°, 135° Total
50 kVp (W anode)	1.0	1000	1.00	1.23×10^{-11}	4.24×10^{-3}	4.24×10^{-3}	6.34×10^{-3}	6.34×10^{-3}
70 kVp (W anode)	1.0	1000	1.00	4.70×10^{-7}	9.44×10^{-3}	0.944	1.38×10^{-2}	1.38×10^{-2}
100 kVp (W anode)	1.0	1000	1.00	9.90×10^{-4}	2.24×10^{-2}	2.34×10^{-2}	3.17×10^{-2}	3.26×10^{-2}
125 kVp (W anode)	1.0	1000	1.00	2.56×10^{-3}	3.73×10^{-2}	3.98×10^{-2}	5.14×10^{-2}	5.39×10^{-2}
150 kVp (W anode)	1.0	1000	1.00	4.42×10^{-3}	5.44×10^{-2}	5.88×10^{-2}	7.36×10^{-2}	7.80×10^{-2}
Radiographic Rm (all barriers)	2.45	1000	1.00	5.32×10^{-4}	3.37×10^{-2}	3.42×10^{-2}	4.83×10^{-2}	4.88×10^{-2}
Radiographic Rm (chest bucky wall)	0.60	1535[a]	1.83	3.88×10^{-4}	4.91×10^{-3}	5.30×10^{-3}	6.94×10^{-3}	7.33×10^{-3}
Radiographic Rm (floor/other barriers)	1.85	1000	1.00	1.44×10^{-4}	2.30×10^{-2}	2.31×10^{-2}	3.31×10^{-2}	3.32×10^{-2}
Fluoroscopy Tube in R & F Rm	12.9	730[b]	0.80	1.16×10^{-2}	0.314	0.326	0.443	0.455
Radiographic Tube in R & F Rm	1.51	1000	1.00	9.42×10^{-4}	2.78×10^{-2}	2.87×10^{-2}	3.92×10^{-2}	4.02×10^{-2}
Chest Room	0.216	1535[a]	2.00	3.81×10^{-4}	2.31×10^{-3}	2.69×10^{-3}	3.22×10^{-3}	3.60×10^{-3}
Mammography Suite (Mo anode)	6.69	720[c]	0.58	1.14×10^{-5}	1.13×10^{-2}	1.13×10^{-2}	4.89×10^{-2}	4.89×10^{-2}
Cardiac Angiography	160	730[b]	0.90	8.83×10^{-2}	2.61	2.70	3.70	3.79
Peripheral Angiography	64.1	730[b]	0.90	3.38×10^{-3}	0.655	0.658	0.946	0.950

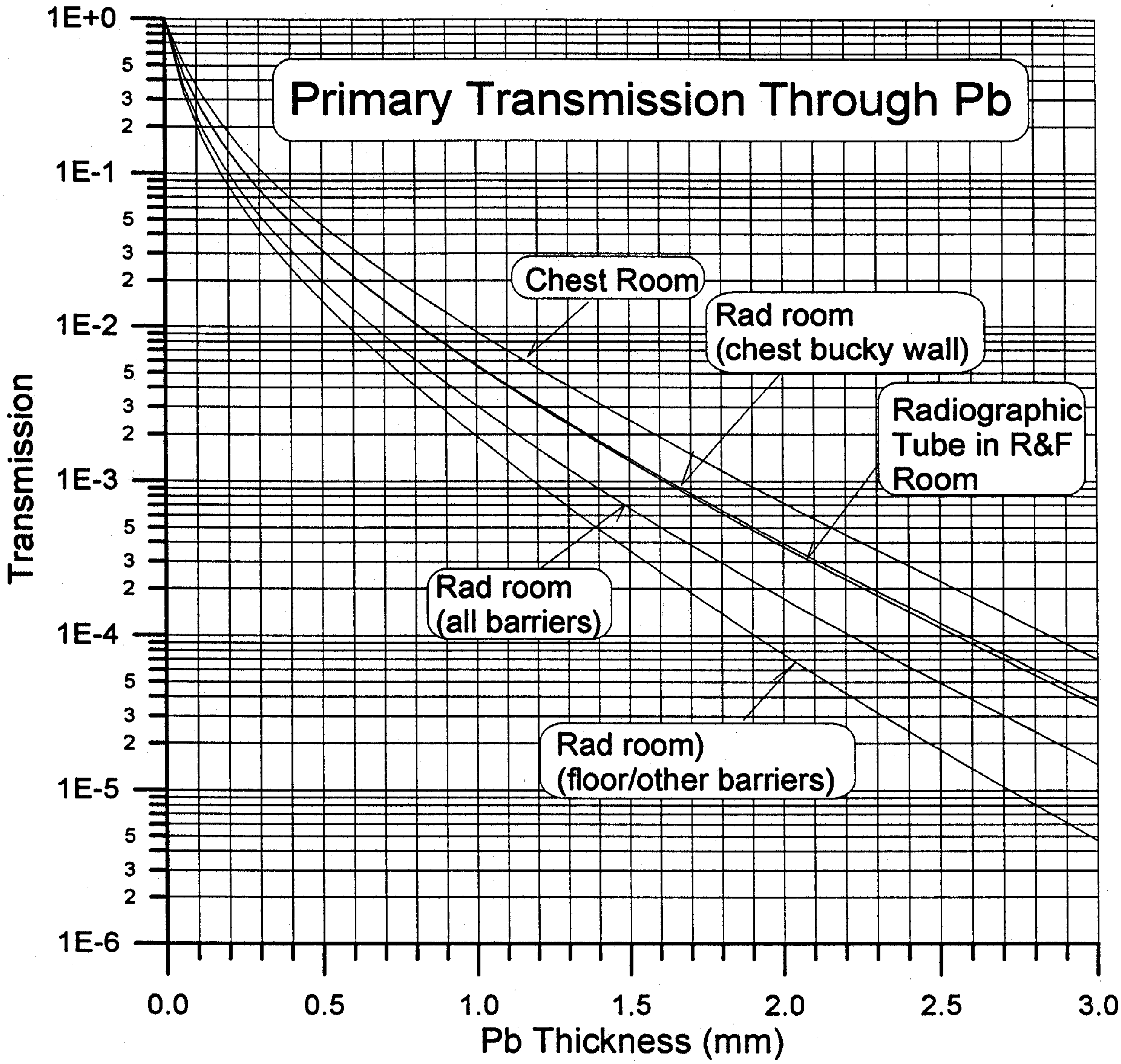


Figure J-1. Broad beam primary transmission through lead for the various workload distributions.
(reproduced from reference 9)

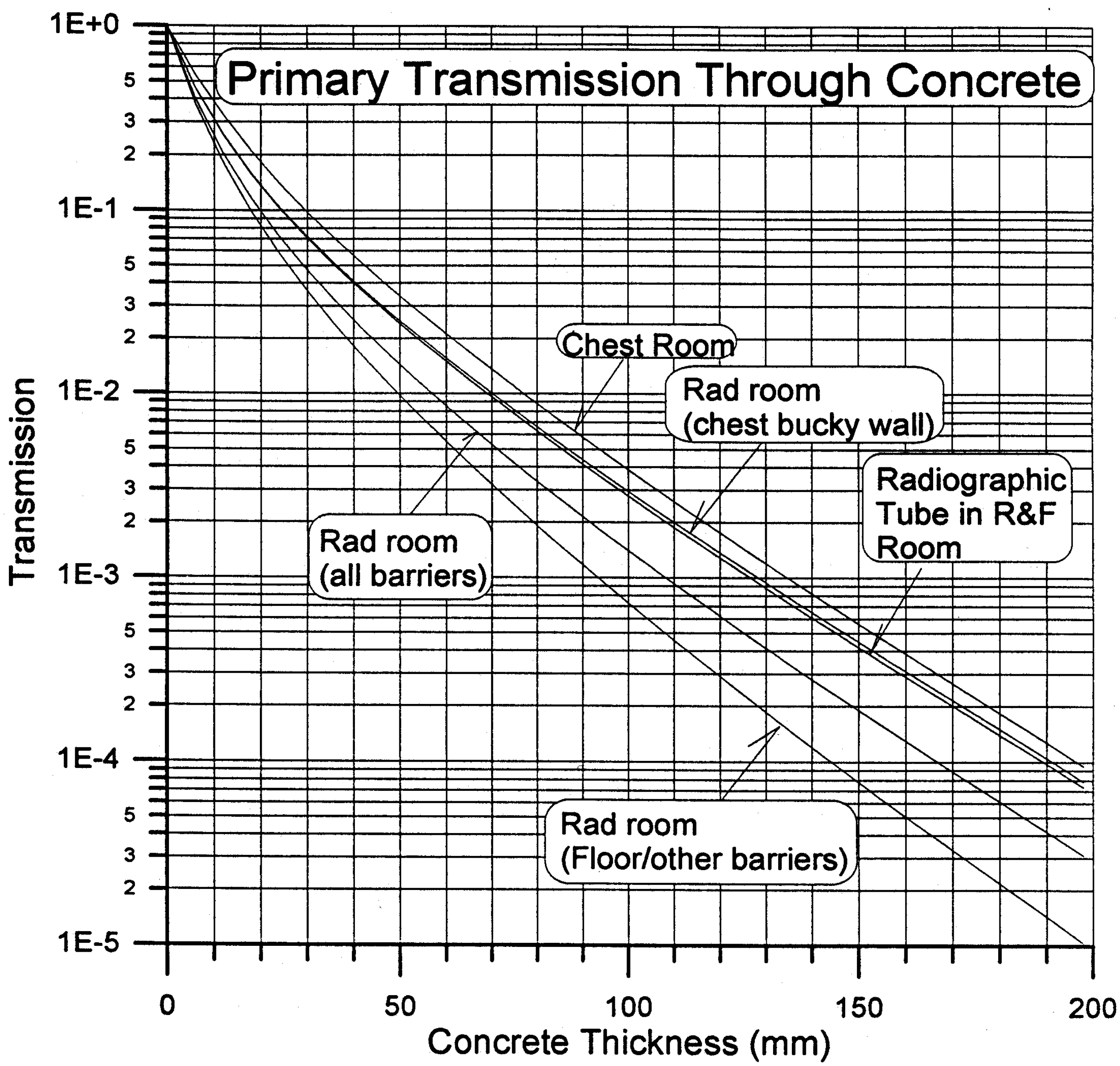


Figure J-2 – Broad beam primary transmission through concrete for the various workload distributions.
(reproduced from reference 9)

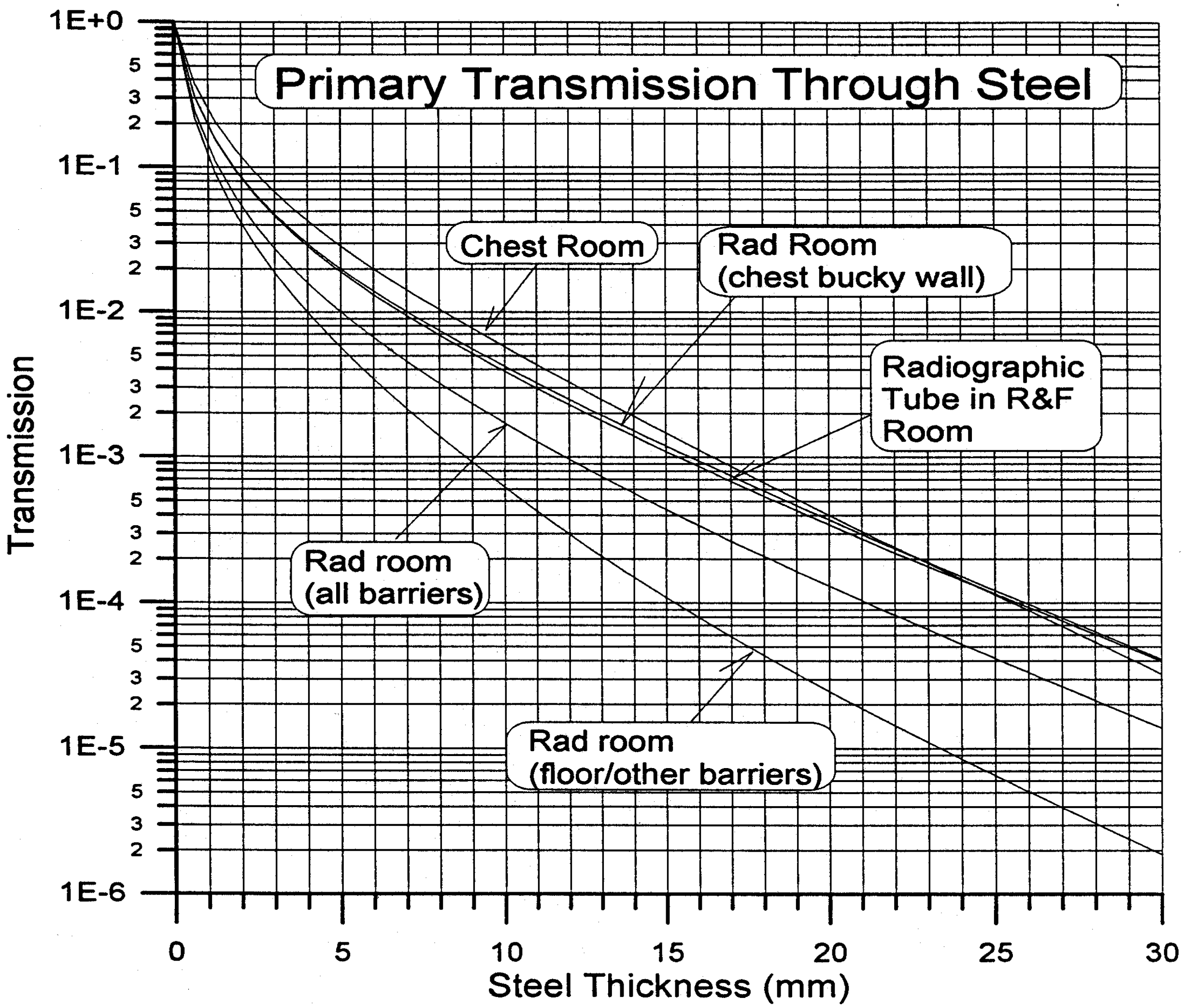


Figure J-3: Broad beam primary transmission through steel for the various workload distributions. (reproduced from reference 9)

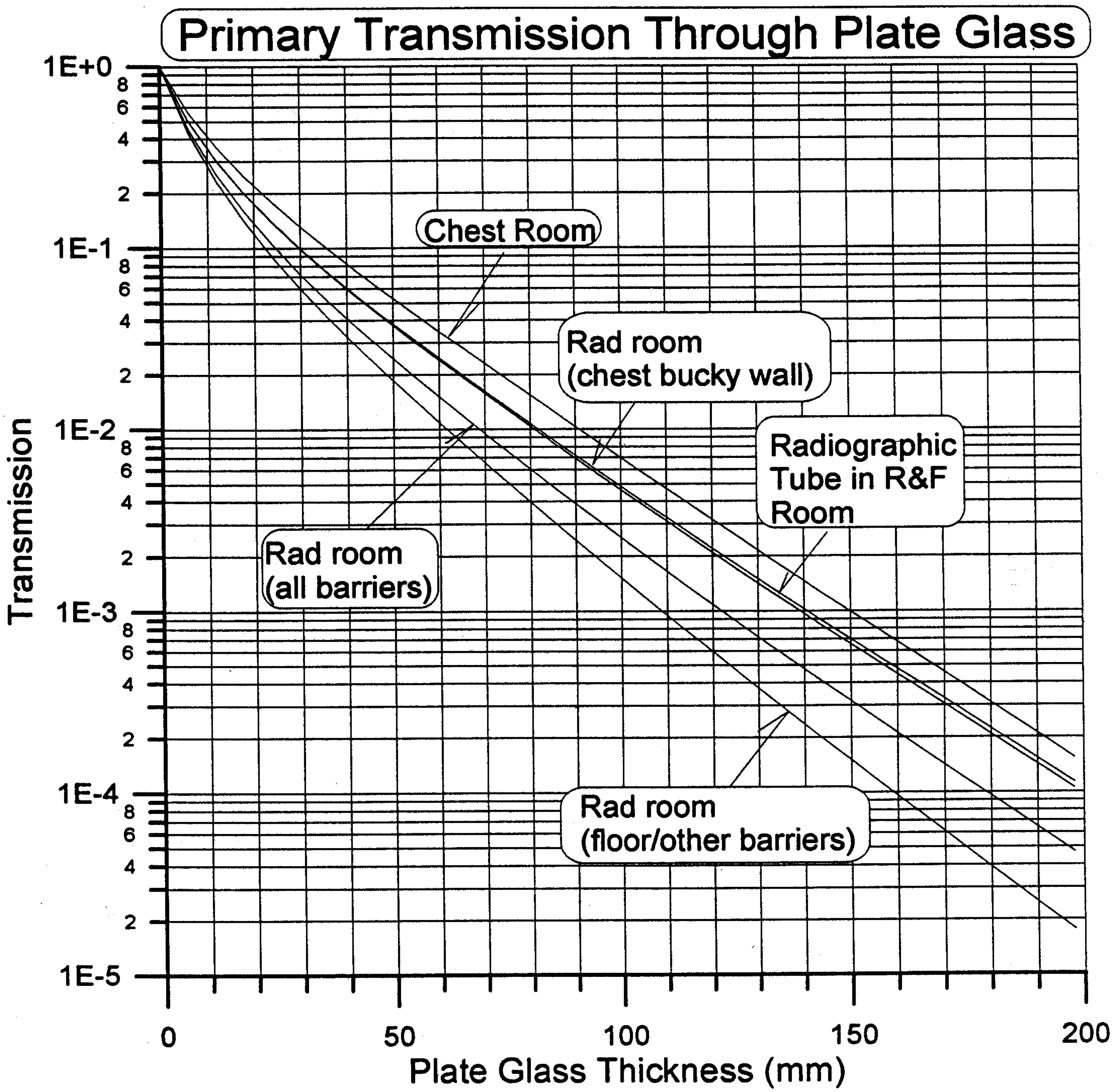


Figure J-4: Broad beam primary transmission through plate glass for the various workload distributions.
(reproduced from reference 9)

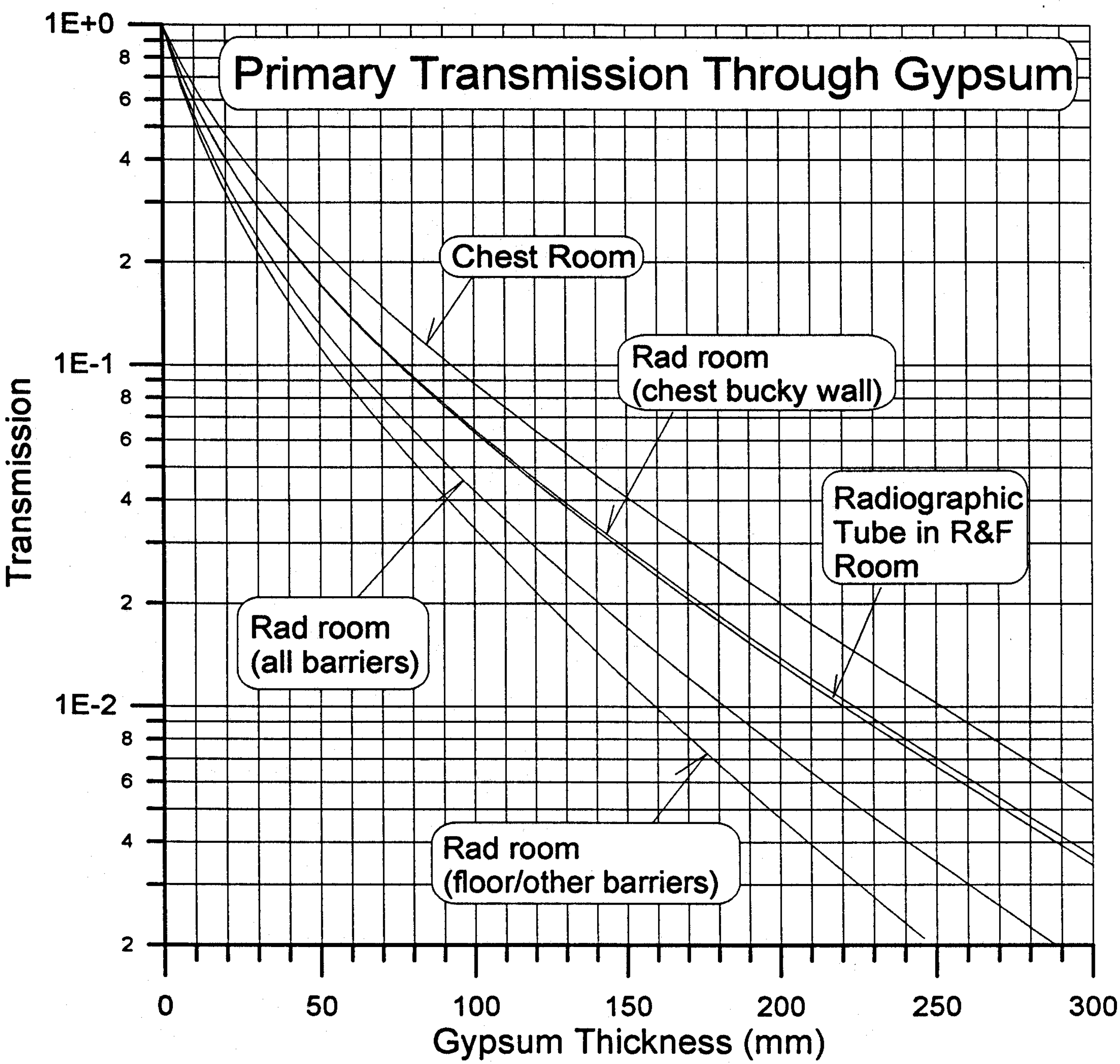


Figure J-5: Broad beam primary transmission through gypsum wall board for the various workload distributions. (reproduced from reference 9)

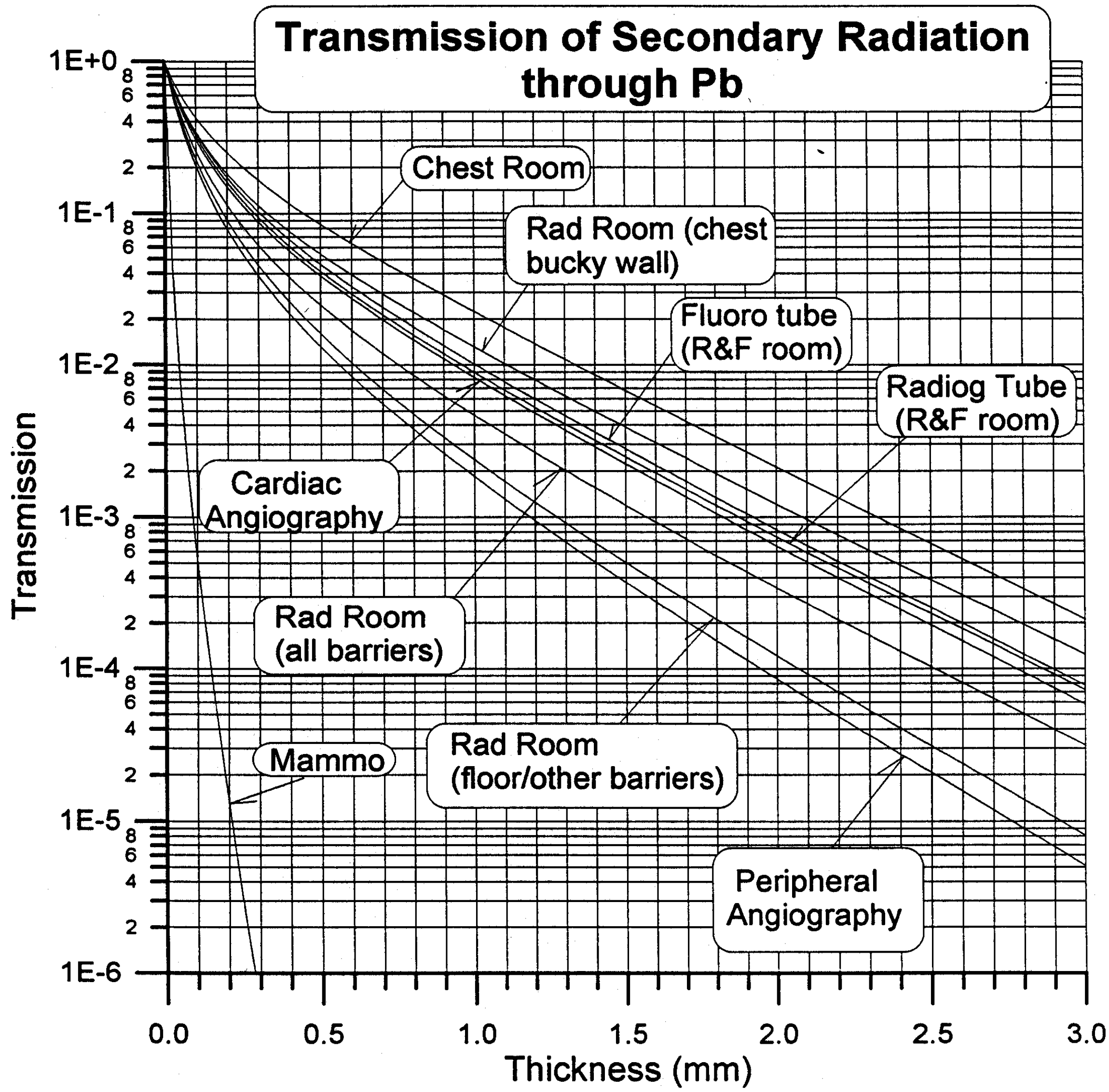


Figure J-6: Transmission of secondary radiation dose through Pb for clinical workload distributions described by Simpkin (3). Transmission calculated for 90 degree scatter due to field size F at distance df listed in Table J-5. (reproduced from reference 9)

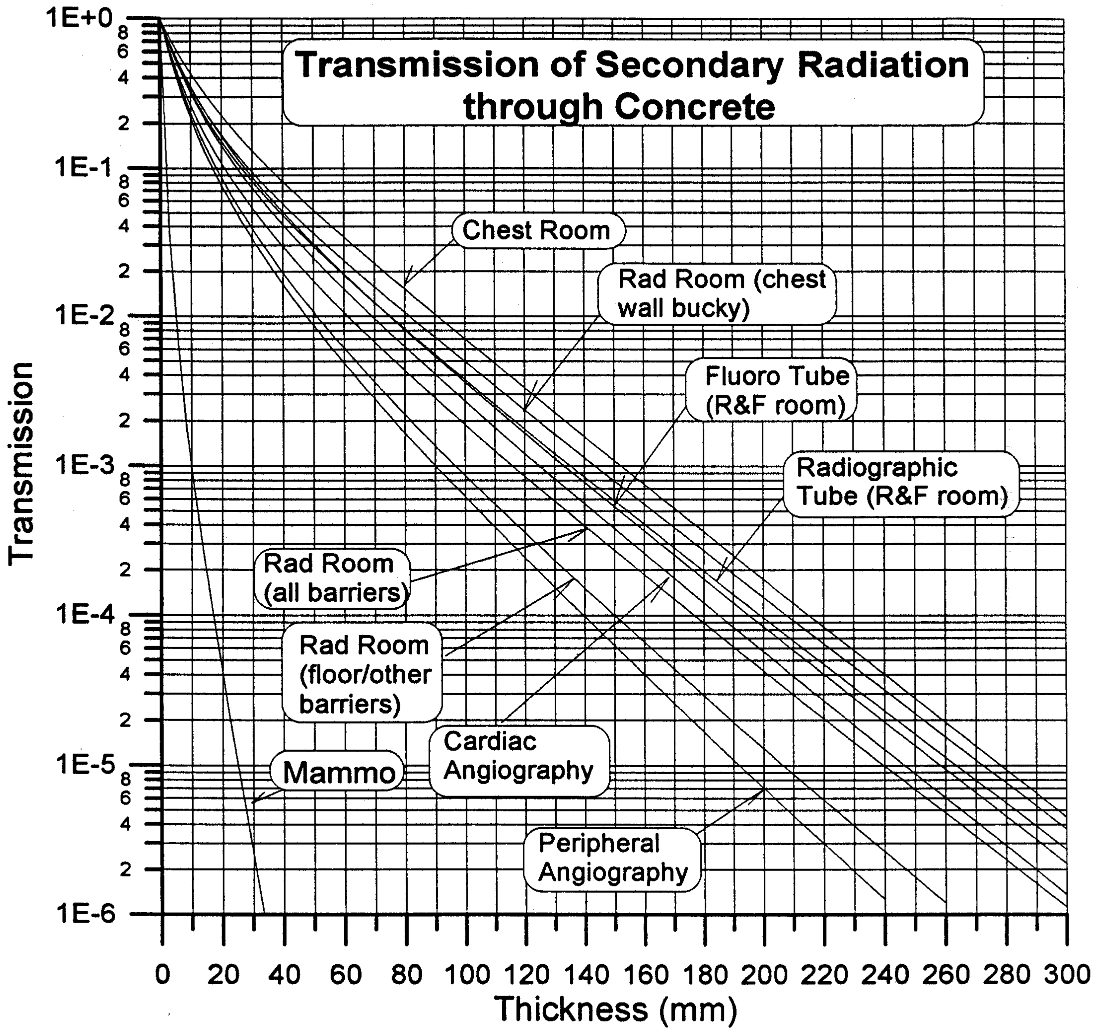


Figure J-7: Transmission of secondary radiation through concrete for clinical workload distributions described by Simpkin (3). Transmission calculated for 90 degree scatter due to field size F a distance d_f listed in Table J-5. (reproduced from reference 9)

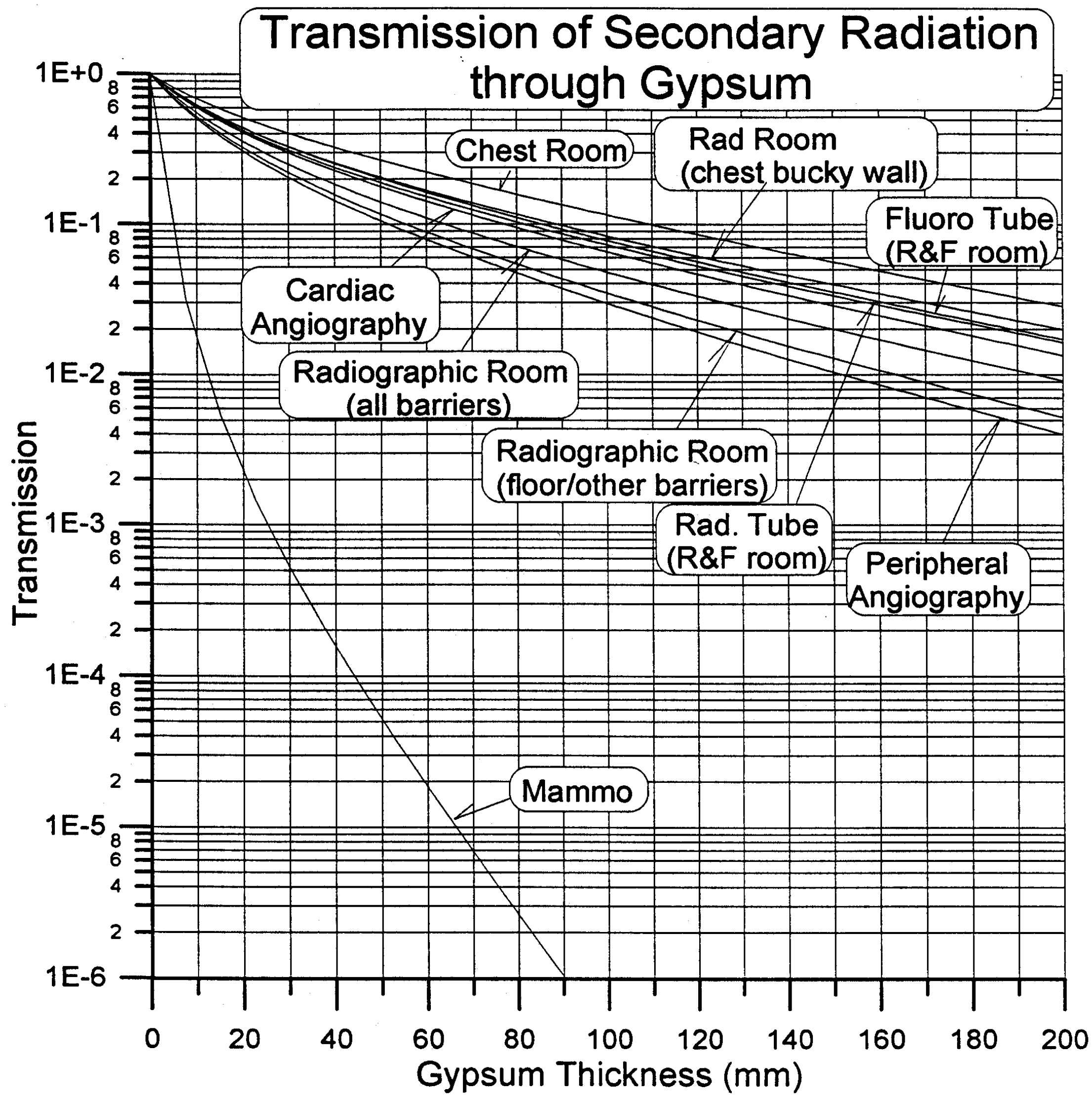


Figure J-8: Transmission of secondary radiation through gypsum for clinical workload distributions described by Simpkin (3). Transmission calculated for 90 degree scatter due to field size F a distance d_f listed in Table J-5. (reproduced from reference 9)

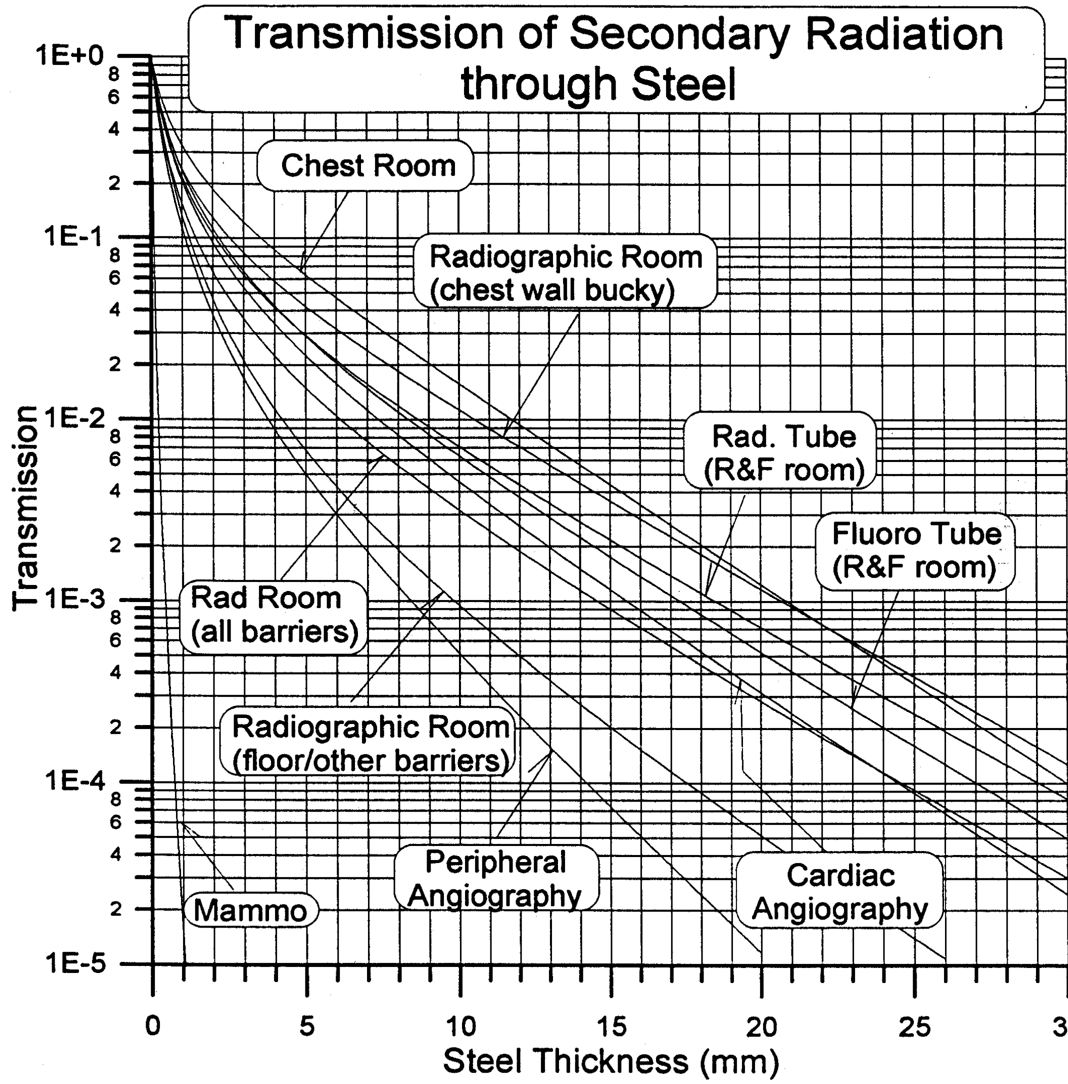


Figure J-9: Transmission of secondary radiation through steel for clinical workload distributions described by Simpkin (3). Transmission calculated for 90 degree scatter due to field size F a distance d_f listed in Table J-5. (reproduced from reference 9)

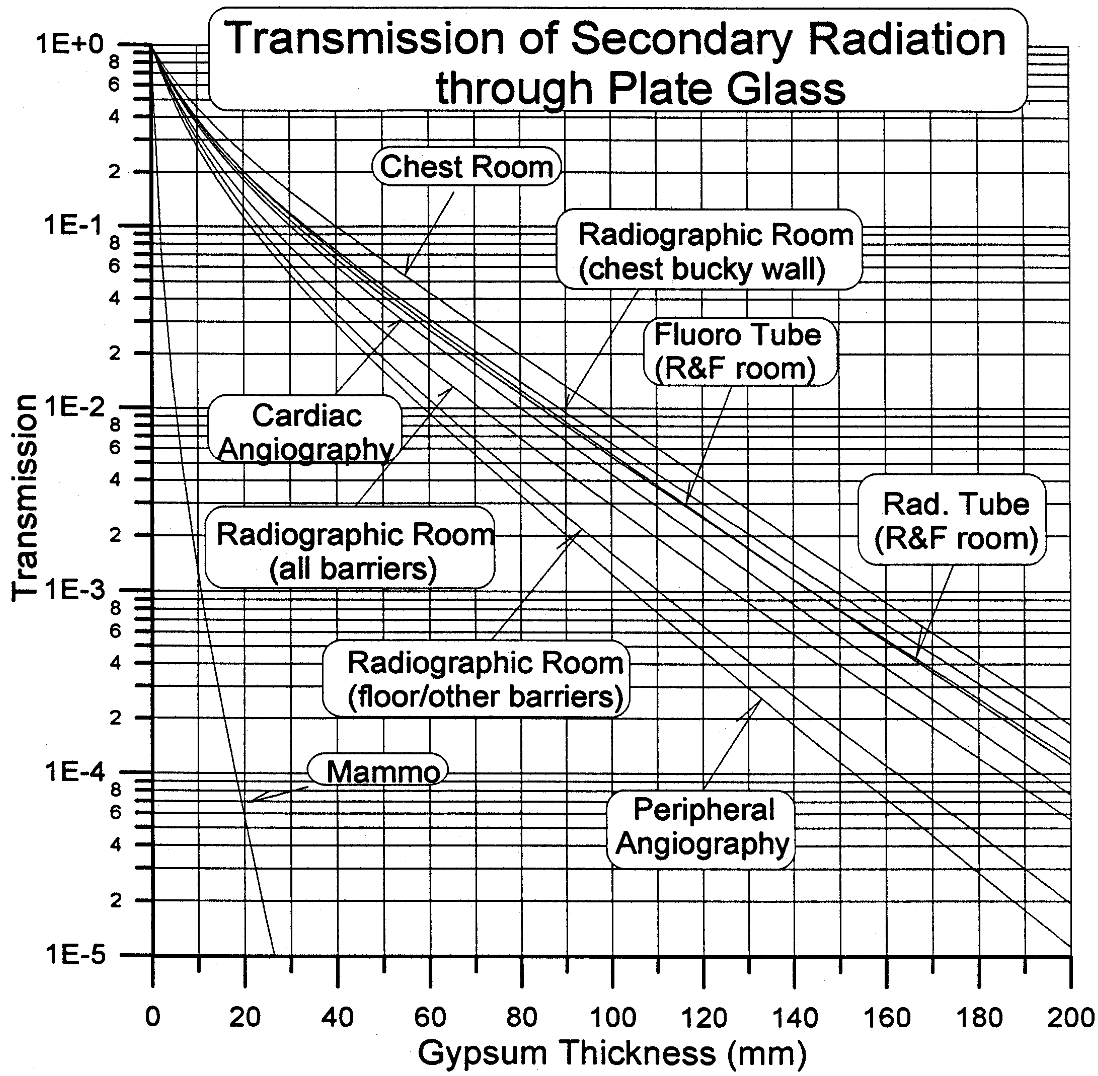


Figure J-10: Transmission of secondary radiation through plate glass for clinical workload distributions described by Simpkin (3). Transmission calculated for 90 degree scatter due to field size F a distance d_f listed in Table J-5. (reproduced from reference 9)

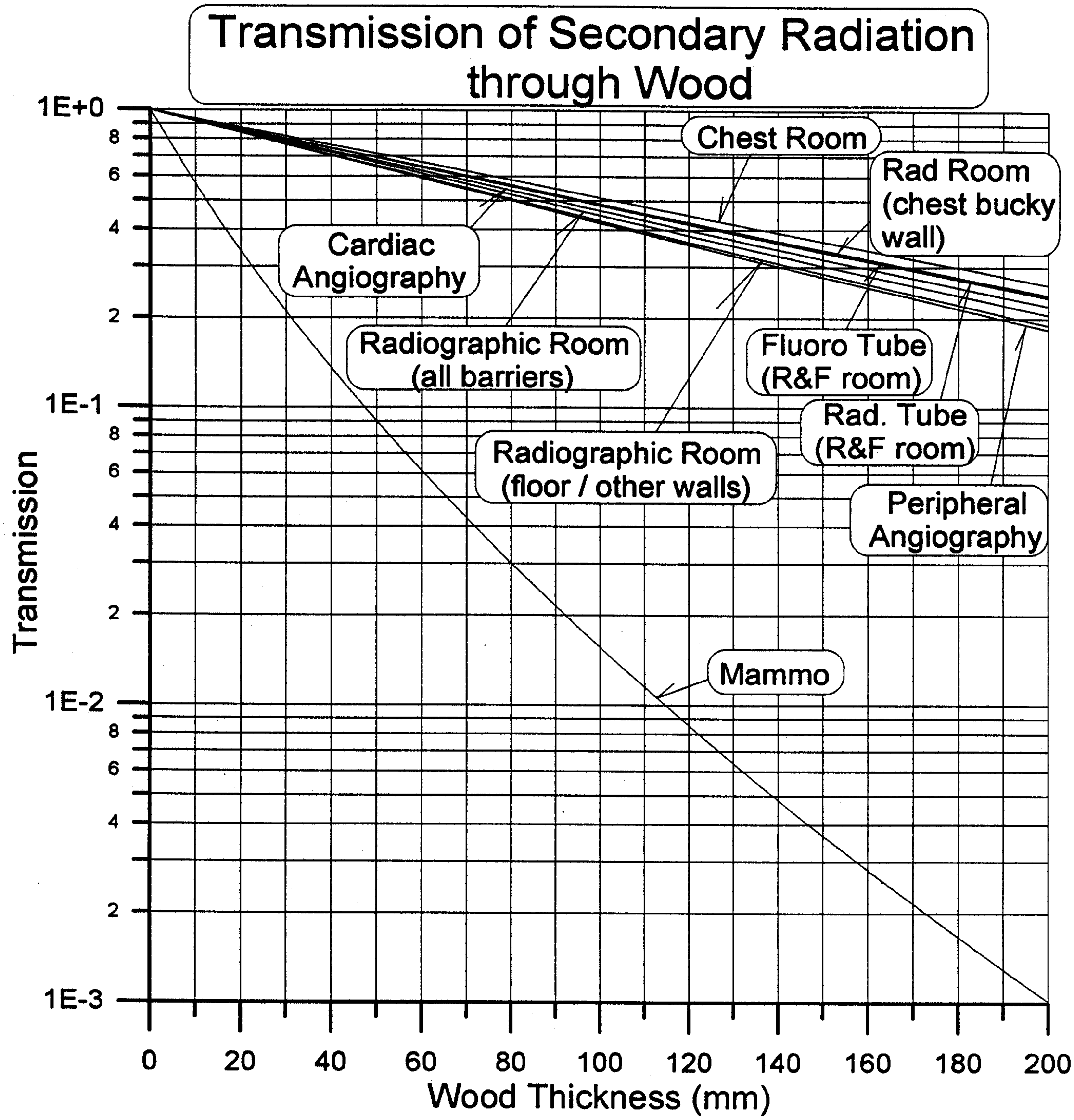


Figure J-11: Transmission of secondary radiation through wood for clinical workload distributions described by Simpkin (3). Transmission calculated for 90 degree scatter due to field size F a distance d_f listed in Table J-5. (reproduced from reference 9)

RADIATION SHIELDING DATA FORMS

RADIATION SHIELDING OF DIAGNOSTIC X-RAY FACILITIES
Revised 01/01 REPORT SYMBOL MED 6470-15

1. FACILITY IDENTIFICATION

a. FACILITY NAME	b. UIC	
c. MAILING ADDRESS	d. BUILDING	e. ROOM

2. STATUS OF THE FACILITY

☐ NEW CONSTRUCTION ☐ SHIOBOARD
☐ ROOM RENOVATION ☐ OTHER ____________________________

3. TYPE OF X-RAY EQUIPMENT (CHECK AS MANY AS APPROPRIATE)

☐ RADIOGRAPHIC ☐ FIXED ☐ DENTAL INTRAORAL
☐ FLUOROSCOPIC ☐ MOBILE ☐ DENTAL PANOGRAPHIC
☐ COMBINATION R/F ☐ OTHER ________________________

4. USE (CHECK ONE)

☐ GENERAL RADIOGRAPHY ☐ MAMMOGRAPHY ☐ OTHER (SPECIFY) _______________________
☐ CHEST RADIOGRAPHY ☐ TOMPGRAPHY
☐ HEAD RADIOGRAPHY ☐ UROLOGY STUDIES

5. FACILITY INFORMATION

FACILITY WORKLOAD (NUMBER OF PATIENTS PER 40 HR WEEK) [ ]

ROOM DIMENSION [ ]
CEILING HEIGHT [ ]

		THICKNESS (mm)	DISTANCE TO SOURCE d (m)	USE FACTOR U
WALL 1 MATERIAL				
WALL 2 MATERIAL				
WALL 3 MATERIAL				
WALL 4 MATERIAL				
WALL 5 MATERIAL				
WALL 6 MATERIAL				
FLOOR MATERIAL				
CEILING MATERIAL				

FUNCTION OF AREAS ADJACENT TO:		CONTROLLED SPACE	DESIGN DOSE P (mSv/wk)	OCCUPANCY FACTOR T
WALL 1 (chest bucky)				
WALL 2				
WALL 3				
WALL 4				
WALL 5				
WALL 6				
BELOW ROOM				
ABOVE ROOM				

6. REFERENCES

a. Dixon, RL and Simpkin, DJ: Applications of new concepts for radiation shielding of medical diagnostic x-ray facilities. RSNA 1998.

7. REPORTED BY:	REVIEWED BY:	DATE:
TITLE:		

RADIATION SHIELDING OF DIAGNOSTIC X-RAY FACILITIES

Revised 01/01 REPORT SYMBOL MED 6470-10

I. FACILITY IDENTIFICATION

a. FACILITY NAME | b. UIC

c. MAILING ADDRESS | d. BUILDING | e. ROOM

II. SHIELDING CALCULATION FOR THE FLOOR OF THE ROOM

a Design Dose, P = mSv/wk b. Occupancy factor, T = c. Patients per week = d. Use Factor, U =

1. PRIMARY BARRIER CALCULATION FOR FLOOR BENEATH THE RADIOGRAPHIC TABLE

a. Unshielded primary dose per patient is [ ] mGy per patient at 1 m.

b. Distance (in m) to a 2 m tall person standing in the area below room [ ]

c. Unshielded primary dose, D(primary) = [ ] mGy/wk

d. Required barrier transmission factor, B = [ ]

e. Using [ ] reference (a) [ ] mm of [ ] is required to attenuate the primary beam.

f. From Table III, reference (a) the typical radiographic table/image receptor is equivalent to [ ] mm of [ ]

g. Net [ ] thickness required in the floor under the x-ray table to attenuate the primary beam to [ ] mSv/wk is [ ] mm.

2. SECONDARY BARRIER CALCULATION FOR FLOOR

a. Unshielded secondary dose per patient is [ ] mGy per patient at 1 m. (assuming 90 degree scatter)

b. Distance (in m) to a 2 m tall person standing in the area below room [ ]

c. Unshielded secondary dose, D(sec) = [ ] mGy/wk

d. Required barrier transmission factor, B = [ ]

e. Using [ ] reference (a) [ ] mm of [ ] is required to attenuate the primary beam.

THE FLOOR SHOULD BE SHIELDED WITH [ ] mm of [ ]

III. SHIELDING CALCULATION FOR THE CEILING OF THE ROOM (purely a secondary barrier)

a Design Dose, P = mSv/wk b. Occupancy factor, T = c. Patients per week =

1. SECONDARY BARRIER CALCULATION FOR THE CEILING

a. Unshielded secondary dose per patient is [ ] mGy per patient at 1 m. (assuming 135 degree scatter)

b. Distance (in m) to a person in the area above room [ ]

c. Unshielded secondary dose, D(sec) = [ ] mGy/wk

d. Required barrier transmission factor, B = [ ]

e. Using [ ] reference (a) [ ] mm of [ ] is required to attenuate the primary beam.

THE CEILING SHOULD BE SHIELDED WITH [ ] mm of [ ]

IV. WALL CONTAINING THE CHEST BUCKY

a Design Dose, P = mSv/wk b. Occupancy factor, T = c. Patients per week = d. Use Factor, U =

1. PRIMARY BARRIER CALCULATION FOR WALL CONTAINING THE CHEST BUCKY

a. Unshielded primary dose per patient is [ ] mGy per patient at 1 m.

b. Distance (in m) to a person standing in the area adjacent to room [ ]

c. Unshielded primary dose, D(primary) = [ ] mGy/wk

d. Required barrier transmission factor, B = [ ]

e. Using [ ] reference (a) [ ] mm of [ ] is required to attenuate the primary beam.

f. From Table III, reference (a) the typical wall-mounted cassette holder is equivalent to [ ] mm of [ ]

g. Net [ ] thickness required in the wall containing the chest bucky to attenuate the primary beam to [ ] mSv/wk is [ ] mm.

2.a. SECONDARY BARRIER CALCULATION FOR THE WALL CONTAINING THE CHEST BUCKY (Secondary radiation generated by the over-table exposures)

a. Unshielded secondary dose per patient is [ ] mGy per patient at 1 m. (assuming 90 degree scatter)

b. Distance (in m) to a person standing in adjacent room [ ]

c. Unshielded secondary dose, D(sec) = [ ] mGy/wk

2.b. SECONDARY BARRIER CALCULATION FOR THE WALL CONTAINING THE CHEST BUCKY (Secondary radiation generated by chest bucky exposures)

a. Unshielded secondary dose per patient is [ ] mGy per patient at 1 m scatter and [ ] for leakage.

b. Distance (in m) to a person standing in adjacent room (from scatter) [ ] from leakage [ ]

c. Unshielded secondary dose, D(sec) = [ ] mGy/wk

Total unshielded secondary dose is the addition of the above doses [ ] mGy/wk

d. Required barrier transmission factor, B = [ ]

e. Using [ ] reference (a) [ ] mm of [ ] is required to attenuate the secondary beam to [ ] mSv/wk.

THE WALL WITH THE CHEST BUCKY SHOULD BE SHIELDED WITH [ ] mm of [ ]

RADIATION SHIELDING OF DIAGNOSTIC X-RAY FACILITIES

Revised 01/01 REPORT SYMBOL MED 6470-10

V. WALL CONTAINING THE DARKROOM

a Design Dose, P = mSv/wk b. Occupancy factor, T = c. Patients per week = d. Use Factor, U =

1. SECONDARY BARRIER CALCULATION FOR THE WALL WITH ADJACENT DARKROOM (Secondary radiation generated by exposures over tabletop)

a. Unshielded secondary dose per patient is mGy per patient at 1 m. (Assuming 90 degree scatter.)

b. Distance (in m) to a person standing in adjacent room

c. Unshielded secondary dose, D(sec) = mGy/wk

d. Required barrier transmission factor, B =

e. Using reference (a) mm of is required to attenuate the primary beam.

THE WALL SHOULD BE SHIELDED WITH mm of

2. SECONDARY BARRIER CALCULATION FOR THE PASSBOX (Secondary radiation generated by exposures over tabletop) Design Dose for film is R

a. Unshielded secondary dose per patient is mGy per patient at 1 m. (Assuming 90 degree scatter.)

b. Distance (in m) to a person standing in adjacent room Cassettes in passbox will be recycled once per day or every patients.

c. Unshielded secondary dose, D(sec) = mGy/wk

d. Required barrier transmission factor, B =

e. Using reference (a) mm of is required to attenuate the primary beam.

THE FRONT DOOR OF THE PASSBOX SHOULD BE SHIELDED WITH mm of

VI. WALL WITH ADJACENT OFFICE SPACE

a Design Dose, P = mSv/wk b. Occupancy factor, T = c. Patients per week = d. Use Factor, U =

1. SECONDARY BARRIER CALCULATION FOR THE WALL WITH ADJACENT OFFICE SPACE (Secondary radiation generated by exposures over tabletop)

a. Unshielded secondary dose per patient is mGy per patient at 1 m. (Assuming 90 degree scatter.)

b. Distance (in m) to a person standing in adjacent room

c. Unshielded secondary dose, D(sec) = mGy/wk

d. Required barrier transmission factor, B =

e. Using reference (a) mm of is required to attenuate the primary beam.

THE WALL SHOULD BE SHIELDED WITH mm of

VII. SHIELDING CALCULATION FOR WALL WITH ADJACENT CORRIDOR

a Design Dose, P = mSv/wk b. Occupancy factor, T = c. Patients per week = d. Use Factor, U =

1. PRIMARY BARRIER CALCULATION FOR WALL WITH ADJACENT CORRIDOR

a. Unshielded primary dose per patient is mGy per patient at 1 m.

b. Distance (in m) to a person standing in the adjacent corridor

c. Unshielded primary dose, D(primary) = mGy/wk

d. Required barrier transmission factor, B =

e. Using reference (a) mm of is required to attenuate the primary beam.

2. SECONDARY BARRIER CALCULATION FOR WALL WITH ADJACENT CORRIDOR

a. Unshielded secondary dose per patient is mGy per patient at 1 m. (assuming 90 degree scatter)

b. Distance (in m) to a person standing in the adjacent corridor

c. Unshielded secondary dose, D(sec) = mGy/wk

d. Required barrier transmission factor, B =

e. Using reference (a) mm of is required to attenuate the primary beam.

THE WALL SHOULD BE SHIELDED WITH mm of

VIII. SHIELDING CALCULATION FOR WALL WITH ADJACENT OUTDOOR AREA

a Design Dose, P = mSv/wk b. Occupancy factor, T = c. Patients per week = d. Use Factor, U =

1. PRIMARY BARRIER CALCULATION FOR WALL WITH ADJACENT OUTDOOR AREA

a. Unshielded primary dose per patient is mGy per patient at 1 m.

b. Distance (in m) to a person standing in the adjacent corridor

c. Unshielded primary dose, D(primary) = mGy/wk

d. Required barrier transmission factor, B =

e. Using reference (a) mm of is required to attenuate the primary beam.

2. SECONDARY BARRIER CALCULATION FOR WALL WITH ADJACENT OUTDOOR AREA

a. Unshielded secondary dose per patient is mGy per patient at 1 m. (assuming 90 degree scatter)

b. Distance (in m) to a person standing in the adjacent corridor

c. Unshielded secondary dose, D(sec) = mGy/wk

d. Required barrier transmission factor, B =

e. Using reference (a) mm of is required to attenuate the primary beam.

RADIATION SHIELDING OF DIAGNOSTIC X-RAY FACILITIES

NAVMED 6470/12 REPORT SYMBOL MED 6470-10

IX. SHIELDING CALCULATION FOR X-RAY CONTROL AREA

a Design Dose, P = mSv/wk b. Occupancy factor, T = c. Patients per week = d. Use Factor, U =

2.a. SECONDARY BARRIER CALCULATION FOR THE WALL CONTAINING THE CHEST BUCKY (Secondary radiation generated by the over-table exposures)

a. Unshielded secondary dose per patient is ______ mGy per patient at 1 m. (assuming 90 degree scatter)

b. Distance (in m) to a person standing in adjacent room ______

c. Unshielded secondary dose, D(sec) = ______ mGy/wk

2.b. SECONDARY BARRIER CALCULATION FOR THE WALL CONTAINING THE CHEST BUCKY (Secondary radiation generated by chest bucky exposures)

a. Unshielded secondary dose per patient is ______ mGy per patient at 1 m scatter and ______ for leakage.

b. Distance (in m) to a person standing in adjacent room (from scatter) ______ from leakage ______

c. Unshielded secondary dose, D(sec) = ______ mGy/wk

Total unshielded secondary dose is the addition of the above doses ______ mGy/wk

d. Required barrier transmission factor, B = ______

e. Using ______ reference (a) ______ mm of ______ is required to attenuate the secondary beam to ______ mSv/wk.

THE X-RAY CONTROL AREA WALL SHOULD BE SHIELDED WITH ______ mm of ______

X. REMARKS

Appendices K through W reserved for future use

Appendix X

Performance Testing Instruments and Accessories
(not all-inclusive)

INSTRUMENTS

KVp Meter
RMI Model # 230
Keithley Model # 35080A, 35075
Victoreen/Nuclear Associates Meter, Model # 07-494DT

Ion Chambers/Electrometers
MDH 1015, 1515, 2015
Keithley Model # 35065
Victoreen RAD CHECK PLUS, Model # 06-526DT
Victoreen 660 Digital Meter, Model 05-747DT

Timer Testers
RMI Model # 231A
Victoreen, Model # 07-457DT
Keithley Model 30030

Mammography:
Victoreen Mammographic kVp Meter, Model # 07-492DT

All-In-One Instruments
Victoreen Comprehensive Test Instrument, Model # 07- 493DT
Keithley TRIAD Model # 35050A

Densitometers
RMI Model # 2-331, 380, 381
Victoreen MINISCAN, 07-424DT, 07-443DT, 07-423DT

Sensitometers
RMI Model # 2-334
Victoreen Model # 07-417, 07-419

ACCESSORIES

Slit Camera
Victoreen Model # 07-624DT
RMI Model # 07-624

Cassette Film/Screen Contact Mesh
Victoreen Mpdel # 07-608DT
RMI Model 142C

Focal Spot Test Tools
Victoreen Model # 07-591DT
RMI Model # 112B

Fluoroscopic Resolution Tools
Victoreen Model # 07-601
RMI Model # 141, 151

Collimator Test Tools
Victoreen Model # 07-661DT
RMI Model # 161B

Beam Alignment Test Tool
Victoreen Model # 07-662DT
RMI Model # 162A

HVL Attenuators
Victoreen Aluminum Filters, Model # 07-430DT
RMI Model # 115A
Keithley Part # 115A

Phantoms
Victoreen Patient Phantom, Model # 07-706DT
CTDI Phantom

Tomography Test Tools
RMI Model # 132
Victoreen Model # 76-400DT

Stepwedge
RMI Model # 117

Appendix Y

References and Recommended Reading

AAPM Report 1, *Phantoms for Performance Evaluation and Quality of CT Scanners*, 1977.

AAPM Report 4, *Basic Quality Control in Diagnostic Radiology*, 1977.

AAPM Report 12, *Evaluation of Radiation Exposure Levels in Cine Cardiac Catherization Laboratories*, 1985.

AAPM Report 15, *Performance Evaluation and Quality Assurance in Digital Subtraction Angiography*, 1985.

AAPM Report 25, *Protocols for the Radiation Safety Surveys of Diagnostic Radiological Equipment*, 1988.

AAPM Report 31, *Standardized Methods for Measuring Diagnostic X-ray Exposures*. 1990.

AAPM Report 35, *Recommendations on Performance Characteristics of Diagnostic Exposure Meters*, 1992.

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Gray, J.E., Winkler, N.T., Stears, J., Frank, E.D. *Quality Control in Diagnostic Imaging*; University Park Press, Baltimore, 1983.

Hendee, W.R., Chaney, E.L., Rossi, R.P. *Radiologic Physics, Equipment and Quality Control*, Year Book Medical Publishers, Inc., Chicago, 1977.

HHS Publication (FDA) . *Quality Assurance for Fluoroscopic X-ray Units and Associated Equipment.* U.S. Department of Health and Human Services, FDA, CDRH. Rockville, 1979.

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HHS Publication (FDA) 80-8096. *Quality Assurance for Conventional Tomographic X-Ray Units*. U.S. Department of Health and Human Services, FDA, CDRH. Rockville, 1979.

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KODAK Process Control Densitometer Operation Manual, Eastman Kodak Company, Health Sciences Division, Rochester, NY 14650, 1-800-388-0608.

Kodak Processor Quality Control Manual Eastman Kodak Company, Health Sciences Division, Rochester, NY 14650, 1-800-388-0608.

Kodak Resources for Health Care Management - Monitoring and Charting Program, Eastman Kodak Company, Health Sciences Division, Rochester, NY 14650.

Lin, P.J.P. *Technical Considerations of Equipment Selection and Acceptance Testing of Cardiovascular Angiography Systems*, 1991 AAPM Summer School Proceedings, 1994.

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Nationwide Evaluation of X-Ray Trends (NEXT), Conference of Radiation Control Program Directors, Inc. Frankfort: CRCPD. 1974-1994.

NCRP Report 102. Medical X-Ray, Electron Beam and Gamma-Ray Protection For Energies up to 50 MeV

NCRP Report 35. Dental X-Ray Protection, 1970.

NCRP Report 49. Structural Shielding Design and Evaluation for Medical Use of X Rays and Gamma Rays of Energies up to 10 MeV

NCRP Report 54. *Medical Radiation Exposure of Pregnant and Potentially Pregnant Women*. National Council on Radiation Protection and Measurements, 1977.

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Appendix Z

Glossary

Acceptance Test: Those tests and measurements that are performed by biomedical equipment maintenance personnel to insure that the diagnostic x-ray system complies with the manufacturer's stated specifications. This also includes a verification that all provisions of the contract have been fulfilled.

Accessible Surface: The external surface of the enclosure or housing provided by the manufacturer**.**

Activity: Number of nuclear transformations per unit time measured in bequerels or curies.

Actual vs. Indicated Field Size: A measurement to assure manual settings of the beam limiting device corresponds to the actual field size. Proper operation of the beam limiting device limits the beam size to the intended area of clinical interest.

Actual Focal Spot: The location at which the anode of an x-ray tube intercepts the electron beam and x-rays are produced.

Air Gap: The gap between a patient and imaging receptor used in magnification examinations that reduces scattered radiation that reaches the film.

Aluminum Equivalent: The thickness of aluminum (type 1000 alloy) affording the same attenuation, under specified conditions, as the material in question.

Analog-to-Digital Converter (ADC): Converts analog signals to digital values for subsequent use in a computer.

Ancillary Equipment: Any equipment that is not a major component of the x-ray system; used in support of radiologic procedures.

Anode: Positive side of an electric circuit such as the x-ray tube anode that includes the target.

Atom: The constituent of matter consisting of a positively charged nucleus surrounded by a cloud of electrons.

Attenuation: The reduction of exposure rate upon passage of radiation through matter.

Attenuation Coefficient (μ): Measure of the x-ray attenuating property of a material measured in **cm -1.**

Auger Electron: Electron (rather than characteristic x-ray) emitted by an excited (energetic) atom.

Automatic Brightness Control (ABC): The device which regulates x-ray tube output to maintain a constant brightness at image intensifier output.

Automatic Exposure Control (AEC): A device that automatically controls one or more technique factors in order to obtain at a preselected location(s) a required quantity of radiation.

Autotransformer: Allows the number of windings included in the circuit to be increased or decreased to produce the output voltage needed.

Beam Hardening: The increase in mean energy of a polychromatic x-ray beam as lower energy photons are preferentially absorbed.

Beam Limiting Device: A device that provides a means to restrict the dimensions of the x-ray or gamma-ray field, also called a collimator or beam defining device.

Beam Quality: A measurement to determine the half-value layer (HVL). HVL relates to the thickness of a specified material, usually aluminum, required to decrease the dosage rate of a beam of x-rays to one-half its initial value. The purpose of the filtration is to absorb the lower energy portion of the x-ray spectrum which would otherwise be absorbed by the patient without contributing to the diagnosis. HVL performance standards are expressed in millimeters of Aluminum.

Becquerel: The SI unit of radioactivity (1 Bq = 1 disintegration per second).

BEIR: The United States National Academy of Sciences Committee on the **B**iological **E**ffects of **I**onizing **R**adiation.

Beta Minus Decay: Nuclear process in which a neutron is converted to a proton with emission of an electron and antineutrino.

Beta Particle: Electron or positron emitted from a nucleus during beta decay.

Beta Plus Decay: Nuclear process in which a proton is converted to a neutron with emission of a positron and neutrino.

Blur: The "smeared out" image of an object produced by an imaging system.

Bremsstrahlung Radiation: General or "braking radiation" x-rays produced when electrons lose energy.

Brightness gain: Ratio of image brightness on an image intensifier output to brightness produced on the input phosphor.

Bucky: Moving grid.

Bucky Factor: Ratio of incident to transmitted radiation for a given grid.

Cassette Holder: A device, other than a spot film device, that supports and/or fixes the position of an x-ray film cassette during a radiographic exposure.

Cathode: Negative side of a x-ray tube containing the filament.

Cephalometric Device: A device intended for the radiographic visualization and measurement of the dimensions of the human head.

Characteristic Curve: Plot of film density against the logarithm of relative exposure, also known as a Hurter and Driffield (H and D) curve.

Characteristic Radiation: X-ray photon of characteristic energy emitted from an atom when an inner shell vacancy is filled by an outer shell electron.

Coefficient of Variation: The ratio of the standard deviation to the mean value of a population of observations.

Coherent Scatter: Photon scattered by an atom without suffering any energy loss, also known as Raleigh scatter.

Collimation: The restriction of the useful (primary) beam to an appropriate size.

Collimator: A device to restrict the size of the X-ray beam. Also called a beam-limiting or beam-defining device.

Compliance Test: Those tests and measurements that are performed by health physicists in order to insure that the diagnostic x-ray system complies with the performance standard contained in this manual and 21 CFR Part 1000, subchapter J.

Compton Interaction: Photon interaction with an outer shell electron resulting in a scattered electron and photon of lower energy.

Cone: A device used to indicate beam direction and establish a minimum source-surface or source-skin distance (SSD). It may or may not incorporate a collimator, also known as a position-indicating device (PID).

Contrast: The difference in signal intensity between an object and the surrounding background.

Contrast Improvement Factor: Ratio of image contrast levels obtained with, and without, the use of scatter reduction systems such as grids or air gaps.

Conversion Efficiency: The percentage of energy deposited into a screen that is converted into light photon energy.

Coulomb: Unit of electric charge.

Curie (Ci): The non-SI unit of activity (1 Ci = 3.7×10^{10} disintegrations per second).

Current: The flow of electric charge measured in amperes.

Dead-man Switch: A switch so constructed that a circuit closing contact can be maintained only by continuous pressure on the switch.

Defect: Any unsafe condition or any failure associated with the use of an x-ray system or component thereof which relates to the health and safety of use by reason of the emission of ionizing radiation for other than its intended purpose.

Densitometer: Device used to measure optical density on film.

Diaphragm: A plate, usually of lead, with a central aperture so placed as to reduce the useful (primary) beam to an appropriate area. (See Collimation.)

Effective Focal Spot: The projection of the actual focal spot on a plane that is perpendicular to the central perpendicular line of the window of the x-ray tube housing or to an agreed specified direction. It is also known as the projected focal spot.

Electron: Fundamental constituent of matter with 1/1836 of the mass of a proton and a negative charge.

Emulsion: Layer of film that contains silver halide grains.

Entrance Skin Exposure: The amount of radiation delivered at the skin surface. It is generally the sum of the air dose at that point and backscatter.

Exposure: Measure of the ability of a source of x-rays to ionize air measured in coulombs per kilogram (C/kg) or roentgens (R).

Filament: Wire on the cathode of a x-ray tube that emits electrons.

Filter: Thin plate, usually made of aluminum, placed in a x-ray beam to absorb unwanted low-energy X-rays.

Film Latitude: The range of exposure levels over which the film may be used without being under- or overexposed.

Film Mottle: Random fluctuations in film density due to the granular nature of the emulsion.

Fluoroscopic Imaging Assembly: A subsystem in which x-ray photons produce a fluoroscopic image. It includes the image receptor(s) such as the image intensifier and spot-film device, electrical interlocks, if any, and structural material providing linkage between the image receptor and diagnostic source assembly.

Flux Gain: The number of light photons at the output phosphor of an image intensifier per light photon produced at the input phosphor.

Focal Spot: Area of anode where x-ray beam is produced.

Focusing Cup: Directs electrons leaving the x-ray tube filament.

Fog Level: Film blackening in the absence of radiation exposure.

Full Width Half Maximum (FWHM): A measure of spatial resolution equal to the width of an image of a line source, defined at points where the intensity is reduced to one-half the maximum intensity.

Geiger Counter: Ionization chamber with a high voltage resulting in amplified output following the detection of an ionizing particle (x-ray photon).

General Purpose Radiographic X-ray System: Any radiographic x-ray system that, by design, is not limited to radiographic examination by specific anatomical regions (e.g., extremities, head or head and neck, thoracic, and abdominal).

Gradient: The average slope of a film characteristic curve, normally obtained between the film densities of 0.5 and 2.0.

Gray: The SI unit of absorbed dose (1 Gy = 1 J/kg).

Grid: Strips of lead in a radiolucent matrix used to reduce scattered radiation.

Grid Line Density: The number of grid lines per centimeter.

Grid Ratio: Ratio of height to separation gap of lead strips in a grid.

Half-value Layer (HVL): Thickness of specified material (e.g., aluminum) needed to reduce the x-ray beam intensity by 50%.

Heat Unit (HU): For single-phase x-ray units, the product of exposure time, peak voltage, and amperage (1J = 1.35 HU).

Heel Effect: The x-ray intensity is greater at the cathode side and is lower at the anode side because of anode absorption.

High-voltage Generator: A device that transforms electrical energy from the electrical potential supplied by the x-ray control to the x-ray tube operating electrical potential. The device may also include means for transforming alternating current to direct current, filament transformers for the x-ray tube(s), high-voltage switches, electrical protective devices and other appropriate components/subsystems, also known as a x-ray high-voltage generator.

ICRP (International Commission on Radiological Protection): International radiation protection agency founded in 1928 that issues recommendations regarding radiation safety.

Image Intensifier (II): Converts incident x-ray pattern to a light image of higher energy density that can be viewed, recorded, or photographed.

Image Receptor: Any device, such as a fluorescent screen or radiographic film, which transfers incident x-ray photons either into a visible image or onto another form which can be made into a visible image by further transformations.

Intensification Factor: Ratio of x-ray exposure without, and with, an intensifying screen to produce a given film density.

Intensifying Screen: Converts x-rays to light, producing many light photons for each absorbed x-ray photon.

Interlock: A limiting device to preclude activation or exposure of a radiation source unless some specific condition is met.

Ionization: Production of electrons and positive ions following the absorption of radiation energy.

Ionization Chamber: Gas chamber used to accurately determine radiation levels based on measurements of charge liberated in a given mass of gas (air).

Ionizing Radiation: Radiation that can result in the ejection of electrons from atoms.

Kilovolt (kV): 1000 volts.

Kilovolts Peak Potential (kVp): The crest value of the potential wave in kilovolts. This indicates the maximum energy level of the X-ray photon.

kV Accuracy: A comparison of measured kV versus that indicated on the machine selector control.

kV Compensation: A comparison of measured kV values at varying mA stations to assure consistency.

Leakage radiation: The radiation emerging from an x-ray unit when the collimators are fully closed.

Limiting Resolution: The highest spatial frequency resolved by an imaging system measured in line pairs per millimeter.

Line Focus Principle: Result of viewing a sloped surface (x-ray tube anode) at an angle, thus reducing its apparent size.

Linear Attenuation Coefficient: The fraction of photons lost from an x-ray beam in traveling a unit of distance measured in cm^{-1}.

Linearity: The ability of an x-ray system to maintain a near constant ratio of the radiation output to the measured product of the tube current (mA) and exposure time(s), mAs, expressed as mR/mAs at various technique factors while maintaining a constant mAs.
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Milliampere (mA): One thousandth of an ampere. This indicates the rate of x-ray production.

Milliampere-second (mAs): The numerical product of the milliamperage and the time in seconds. With all the other factors held constant, the film density is related to mAs and will not change as the mA and the time are varied; as long as they are varied reciprocally and their product is unchanged.

mA Linearity: A comparison of X-ray exposure at adjacent mA settings to assure consistency. Performance standards for linearity are expressed using a statistical ratio (Coefficient of Linearity).

Multipurpose X-ray System: (See General Purpose Radiographic X-ray System)

New X-ray Equipment/system: X-ray equipment/system that was manufactured and installed after 1 August 1974. Therefore, old equipment/system is that manufactured prior to 1 August 1974.

Nuclear Regulatory Commission (NRC): United States federal agency ultimately responsible for regulating nuclear materials.

Operator: The person actually in control of the equipment when exposures are being made.

Optical Density (OD): Measure of the degree of film blackening using a logarithmic scale.

Penumbra: Geometric unsharpness caused by focal spot size.

Phantom: A device that absorbs and scatters X-rays in approximately the same way as tissues of the body. It is used, instead of a human, while making measurements that include scattered radiation.

Position Indicating Device (PID): A device on a dental radiographic x-ray system used to incorporate the beam position and to establish a definite SSD. The devices may or may not incorporate or serve as a beam-limiting device.

Positive Beam Limiting Device (PBL): A device that automatically adjusts the X-ray field to the size of the film cassette in the cassette holder. The PBL device automatically limits the beam size to the area of clinical interest.

Primary Beam: See Useful Beam

Protective Barrier: A barrier of radiation-absorbing materials used to reduce radiation exposure to the required value for radiation protection purposes.

Primary Protective Barrier: A barrier sufficient to attenuate the useful (primary) beam to the required value for radiation protection purposes.

Secondary Protective Barrier: A barrier sufficient to attenuate the stray radiation to the required value for radiation protection purposes.

Quality Assurance: The portion of the Radiation Protection Survey which monitors or audits film processing and its effects on radiation exposure.

Rad: Stands for “radiation absorbed dose,” which is a non-SI unit of absorbed dose (1 rad = 100 erg/g).

Radiation (ionizing): Any electromagnetic or particulate radiation capable of producing ions, directly or indirectly, by interaction with matter. (See also leakage radiation, scattered radiation, stray radiation, useful beam)

Radiation Protection Survey: An evaluation of existing or potential radiation hazards associated with the use of x-ray equipment under specified conditions.

Radiographic Mottle: Random density fluctuations (noise) observed in an image after a uniform exposure.

Rare Earth Screen: Radiographic screen containing rare earth elements.

Rated Line Voltage: The range of potentials, in volts, of the supply line specified by the manufacturer at which the x-ray system is designed to operate.

Rated Output Current: The maximum allowable load current of the x-ray high-voltage generator.

Rated Output Voltage: The allowable peak tube potential, in volts, at the output terminals of the x-ray high-voltage generator.

Reassembly: The installation of one or more components or subsystems that were previously assembled and used as an x-ray system.

Reciprocating Grid: A grid that moves during a radiographic exposure and smears out the grid lines in the resultant image; also known as a Bucky.

Rectification: Changing an alternating voltage into one that retains a selected polarity (AC to DC).

Rem: Stands for "radiation equivalent man," a non-SI unit of dose equivalent.

Reproducibility: A measure of X-ray consistency for a given technique setting (kVp, mA and time). Performance standards are expressed using a statistical test (Coefficient of Variation). The ability of an x-ray system to maintain near constant radiation exposure (mR) at specified techniques for repetitive exposures.

Resolution: A manifestation of sharpness and the minimum separation at which two adjacent objects can be distinguished as individual objects. The resolution capability of a focal spot is generally identified as the equivalent focal spot.

Roentgen (R) **:** Unit of exposure that measures charge liberated in air.

Scatter: Radiation deflected from its initial direction.

Scattered Radiation: Radiation that, during passage through matter, has been deviated in direction. It will also have been modified by a decrease in energy.

Scintillator: Material that emits light after absorption of radiation.

Screen Mottle: Random fluctuations in image density produced because of imperfections and variations in screen thickness.

Screen Unsharpness: Blur caused by light diffusion within the intensifying screens.

Secondary Radiation: Radiation such as characteristic x-rays produced as a result of the absorption of primary radiation.

Self-rectification: A reference to the fact that electrons cannot flow from the anode to the cathode in an x-ray tube.

Shutter: In diagnostic equipment, an adjustable device used to collimate the useful (primary) beam.

Signal-to-noise ratio (SNR): Used in imaging to measure the ratio of signal intensity to the image noise level.

Source: The focal spot of the x-ray tube, also known as the tube target.

Source-to-Image Distance (SID): The difference from the X-ray tube target (anode) to the X-ray film or other image receptor. The performance standards are expressed as a percentage of actual distance to the tube head distance setting.

Source-to-Skin Distance (SSD): The distance from the X-ray tube target (anode) to the skin of the patient where the X-ray beam enters the body. The performance standard requires a minimum distance be maintained depending upon machine parameters.

Space Charge: Result of an electron cloud around the filament in an x-ray tube.

Spatial Resolution: Ability to discriminate between two adjacent high-contrast objects.

Spot Film Device: A device intended to transport and/or position a radiographic image receptor between the x-ray source (tube) and the fluoroscopic image receptor. It includes a device intended to hold a cassette over the input end of an image intensifier for the purpose of making a radiograph.

Stationary (Fixed) Equipment: Equipment that is installed in a fixed location.

Stray Radiation: The sum of leakage and scattered radiation.

Streak Artifacts: Artifacts seen in computed tomography that may be caused by patient motion or metallic implants.

Subject Contrast: Difference in x-ray beam intensities emerging from an object.

Technique Factors: The conditions of operation. Specified as follows:

- **a.** For a capacitor energy storage x-ray system, the peak tube potential in kVp and the quantity of charge in mAs.
- **b.** For a field emission x-ray system rated for pulsed operation, the peak tube potential in kVp, and the number of x-ray pulses.
- **c.** For all other x-ray systems, the peak tube potential in kVp and either the tube current in mA and exposure time in seconds, or the product of tube current (mA) and exposure time(s) in mAs.

Tenth-value Layer (TVL): Thickness of material needed to reduce an x-ray beam intensity to 10% of its initial value.

Tube Housing Assembly: A device that includes the insert, high-voltage and/or filament transformers and other components/subsystems when they are contained within the tube housing.

Timer Linearity: A comparison of the X-ray exposure at different machine timer settings to ensure consistency. Performance standards are expressed as a Coefficient of Linearity.

Useful Beam: Radiation that passes through the window, aperture, cone or other beam-limiting device of the source housing when the exposure switch or timer is activated. Sometimes called the “primary beam.”

Visible Area: That portion of the input surface to the image receptor over which incident x-ray photons are producing a visible image.

Voltage: Electrical potential difference.

Wavelength: The distance between two consecutive crests of a wave.

X-rays: High-frequency (energetic) electromagnetic radiation produced using electrons.

X-ray Beam/Light Field Alignment: A comparison of the dimensions of the X-ray beam to the corresponding light field dimensions. This is an indication of whether the X-ray beam is limited to the area of clinical interest.

X-ray Control: A device that controls input electrical power to the x-ray high-voltage generator/x-ray tube. It includes components/subsystems such as timers, phototimers, automatic brightness stabilizers, and similar devices which control and display technique factors of an x-ray exposure. Normally there are components/subsystems which permit line voltage compensation.

X-ray Equipment: An x-ray system, subsystem, or component thereof.

X-ray Field/UTIR Centers Comparison: A measurement of the center of the X-ray beam as it corresponds to the film cassette holding device (Bucky). Centers misalignment adversely affects the diagnostic quality of the image.

X-ray system: An assemblage of components or subsystems for the controlled production of x-rays. This system includes as a minimum an x-ray high-voltage generator, an x-ray control, a tube housing assembly, a beam-limiting device, and the necessary supporting structures. Additional components which function with the system are considered integral parts of the system, also called x-ray equipment.

X-ray Tube: Any electron tube that is designed for the conversion of electrical energy into x-ray energy. Also called a tube.